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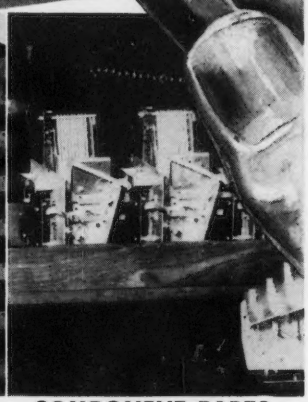

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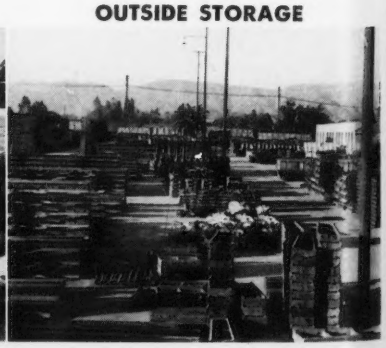

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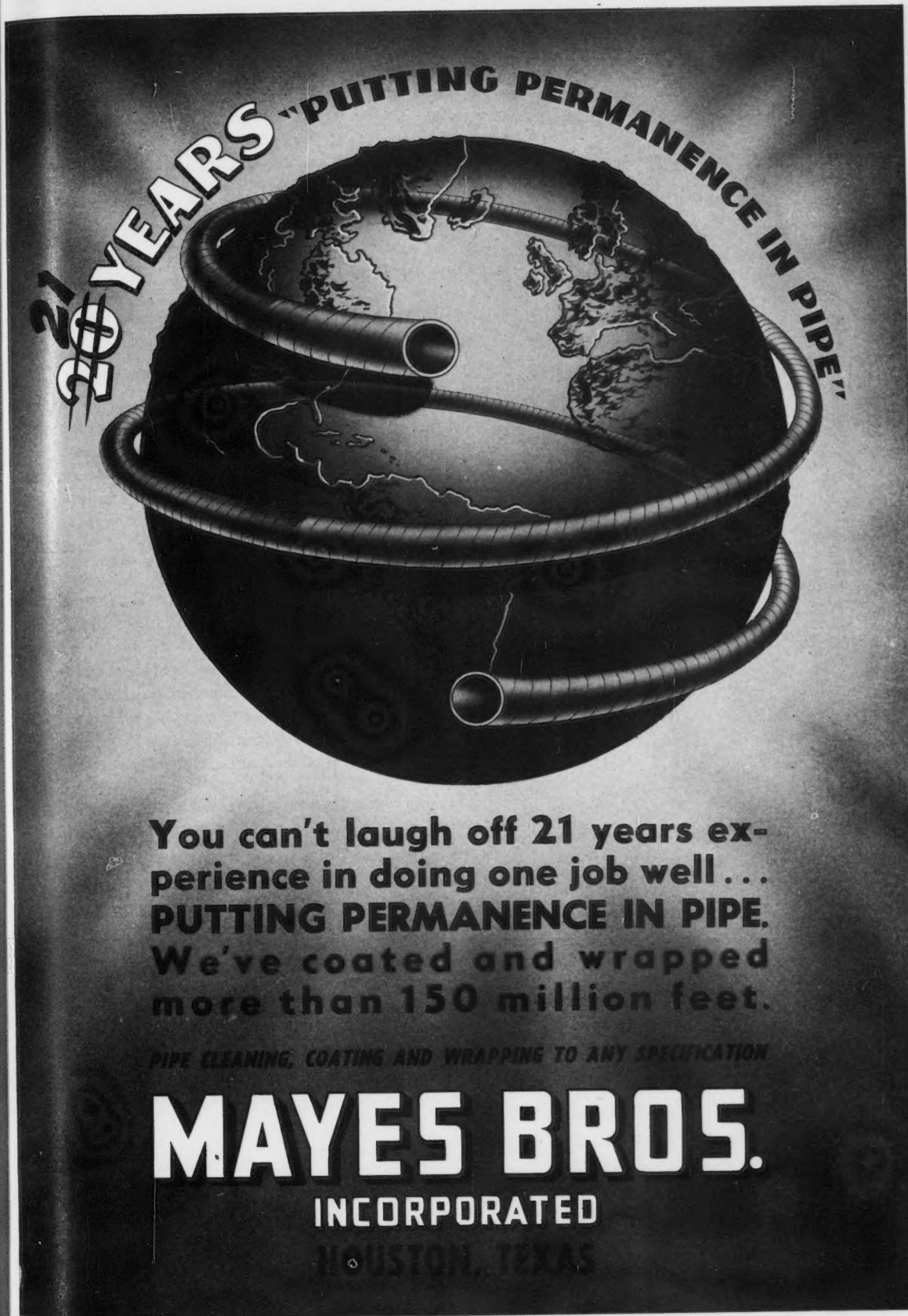
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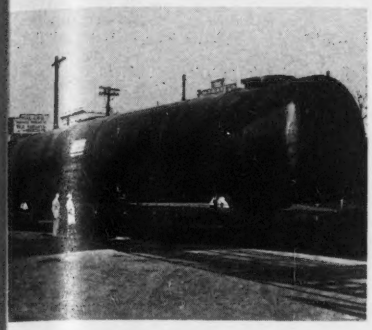

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Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

Corrosion is Indexed Regularly by Engineering Index.

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CORROSION
Research and Control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., to provide a permanent record of progress in the control of corrosion as described in papers prepared for the Association and from other sources.

Vol. 5 FEBRUARY, 1949 No. 2

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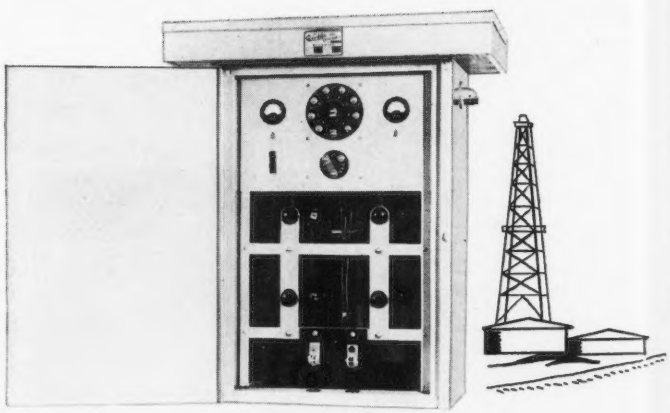

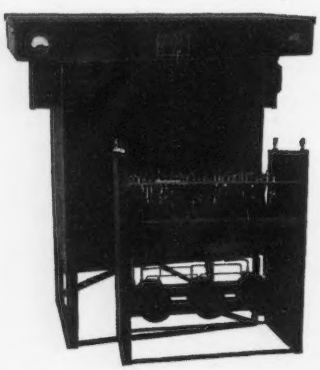

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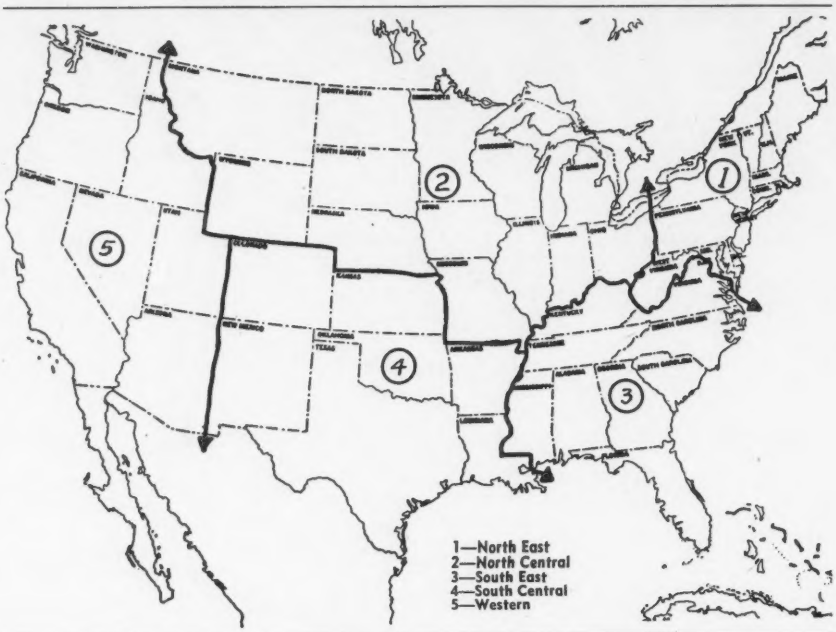

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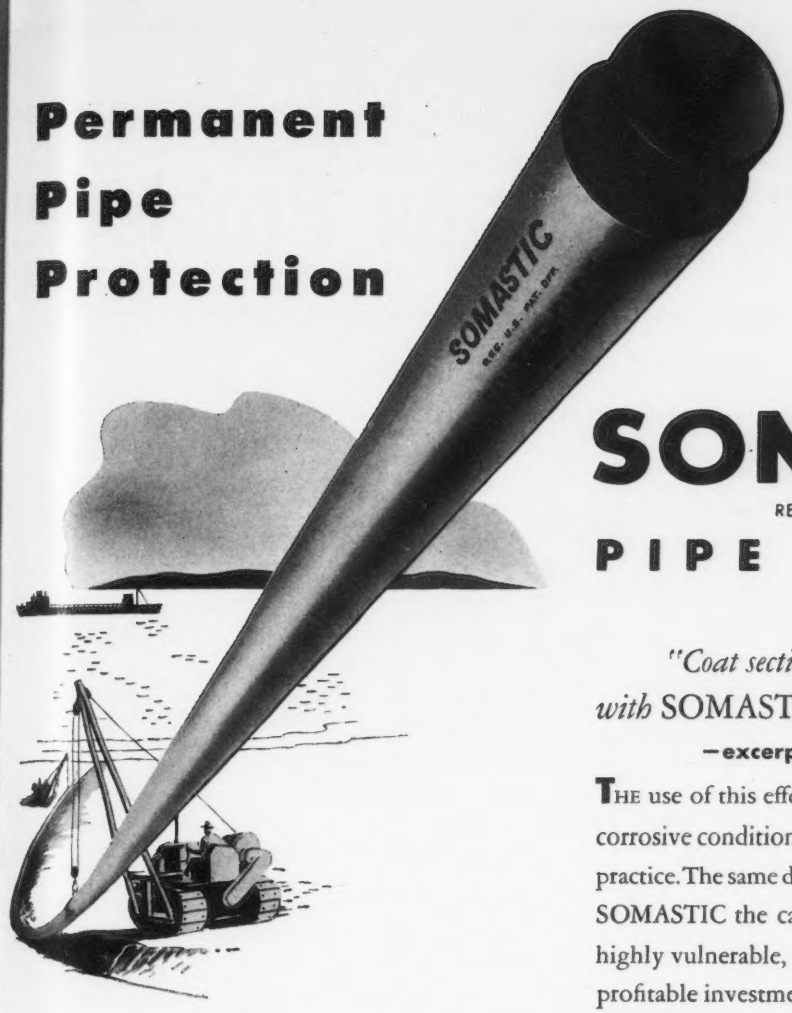

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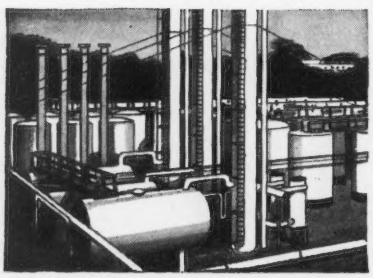

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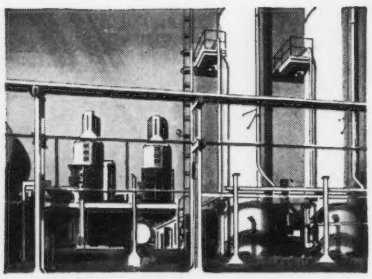
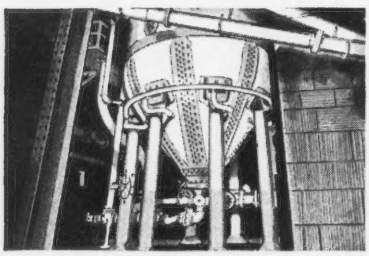
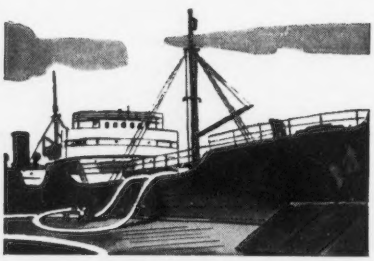


2. A LARGE OIL COMPANY applied Ucilon 400 where equipment needed protection from acid and caustic spillage. Corrosion was checked. They report Ucilon standing up where all other coatings tried had failed.



3. A PAPER MILL tried Ucilon 400 on a pulp chute that had required excessive maintenance under constant motion of pulp, soda ash and water at 140°F. Even with fewer coats, Ucilon lasted *3 times* longer than former coatings!



4. A TANKER had Ucilon-coated panels in the hold which carried 100-octane gas, diesel oil, kerosine, salt water ballast. The Ucilon coatings were still good *after 10 months!* No previous coating had survived even one cargo.

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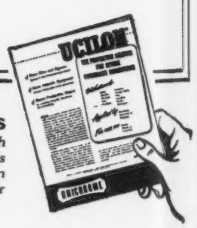

SEND FOR THIS BULLETIN *which gives more details on various Ucilon coatings and their properties.*

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A Message from Your Officers

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OVER A LONG period of years the various industry and trade associations and engineering societies have contributed materially to the industrial development and technological advances made in the United States and other countries throughout the world.

Nearly all of these nationally known groups, such as the American Gas Association, American Petroleum Institute, Edison Electric Institute, American Institute of Chemical Engineers, American Society of Civil Engineers and many others, operating through voluntary committees composed of the best minds of industry, have through study and discussion of basic problems, developed solutions to a wide range of perplexing questions. These organizations generally have been engaged on the problems and exchange of information relating to a particular industry or particular technical field.

The problem of mitigation of corrosion is related to all industry, and for this reason the National Association of Corrosion Engineers has before it a broad field of activity. Starting initially in the field of buried pipe lines and the application of cathodic protection, it has broadened its activities into other fields, as is best indicated by the wide range of subjects covered at its last annual convention.

Like other associations, it must work through its committees. These committees, through the wide contacts of their membership, are in touch with the full range of activities in the corrosion field. Through discussions and reports they can make important contributions to the mitigation of corrosion which can be of great interest and value to industry throughout the country.

Just how valuable these contributions will be will depend upon the talent that can be attracted to these committees, the support given them, the work which they undertake and the manner in which they tell of their findings. The results of the work of the technical committees will be of greater value if the reports describing them are well prepared and promptly made available to the NACE membership.

The backbone of the National Association of Corrosion Engineers, as with other similar organizations, is the activities of its technical committees. As has been pointed out in previous articles, these activities should deal not only with technological advances, but with the practical application of these advances, including the economic problems involved.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.

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Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid*

By W. E. PRATT and E. T. COLLINSWORTH, JR.

INDUSTRIAL USERS are familiar with a number of cases in which alloys known to be resistant to sulphuric acid unaccountably have failed in service. Field investigation by the authors' company indicates that in most such cases relatively large areas of lead were in metallic contact with the alloy which failed. Very frequently this failure has been laid to a change in the position (activation) of the alloy in the galvanic series for the particular electrolyte, causing it to become anodic to the lead.

This puzzling problem stimulated investigation by the Worthington Pump and Machinery Corporation and some of the results of this investigation already have been published. One of the authors' papers[1] discusses the potential change between Worthite* and lead, with Worthite becoming anodic in a 20 percent hot sulfuric acid solution as follows:

> "This is believed to represent the most violent change of potential ever recorded for stainless steels and may have included a simultaneous change in the potential of the lead as the environment was altered by the corrosion of the steel and the evolution of hydrogen.

This article reports results of some preliminary investigations to determine the exact mechanism involved in the changes of the relative potentials of lead and some stainless steels, notably Worthite in sulfuric acid as an electrolyte.

In the paper referred to above, one of the cases described involved a lead-lined pickling machine in which Worthite pumps and conveyor rolls were viciously attacked by galvanic action in 20 percent hot sulfuric acid. Experiments disclosed that the apparent cause of the anodic position of Worthite relative to the large areas of lead surface was the lack of oxidizing capacity of the acid. By adding a small amount of sodium chromate to the pickling acid the condition was corrected, the Worthite becoming passive and cathodic to the lead with no further corrosion failure occurring.

Subsequently, other failures of stainless steels were reported in connection with sulfuric acid diluting equipment. In two such cases it was found that 66° Bé sulfuric acid was poured into water in a lead-lined tank without adequate mixing. This resulted in temperatures being recorded of 240° F. and 140° F. when diluting to 50 percent and 25 percent sulfuric acid, respectively.

Figure 1 shows the lead-lined tank in which sulfuric acid was diluted to 50 percent by pouring a carboy of acid into approximately 1½ carboys of water in about 30 seconds, resulting in a temperature of 240° F. The practice was to pump this 50 percent hot sulfuric acid immediately by the Worthite pump shown into a rubber-lined pickling machine contain-

W. E. PRATT

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E. T. COLLINSWORTH, JR.

Presently on study leave at Harvard Graduate School of Business Administration from a New York City management consulting company, Mr. Collinsworth received a B.S. in chemical engineering from the University of Tennessee. While with Worthington Pump and Machinery Corporation he was in the department of research and development and for two years investigated corrosion phenomena, after which he was transferred to technical sales division.

*Fe: 20 CR; 24 Ni; 0.07 max C; 3.25 Si; 3 Mo; 1.75 Cu; 0.06 Mn.

★A paper presented at Corrosion Section of Electrochemical Society Meeting, Columbus, Ohio, April 12-16, 1948.

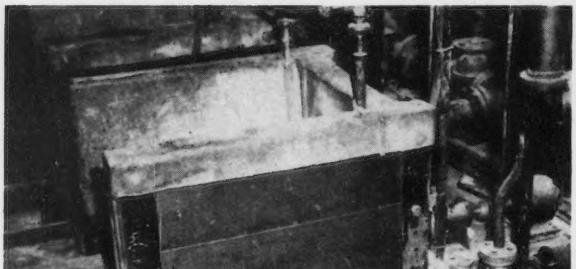


Figure 1—Lead-lined sulfuric acid diluting tanks, with Worthite pumps. Method of diluting raised the acid temperature above boiling point of water, thus deaerating the solution, heavily sulfating the lead and causing galvanic corrosion of the Worthite pump.

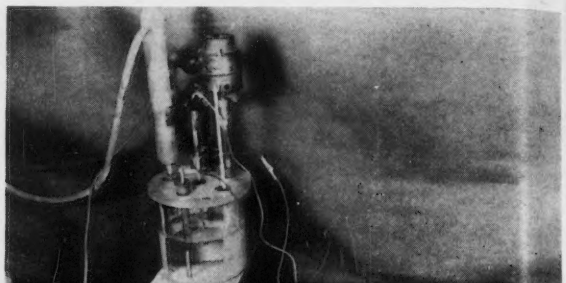


Figure 2—Apparatus used in investigation.

ing cold water. This diluted the acid to about 10 percent, causing cooling which protected the rubber lining. The Worthite pump, however, was corroded in six months to the point of failure of some parts.

In determining the cause of failure, the Worthite pump was insulated completely from the lead-lined tank and piping, a potentiometer then indicated the Worthite was anodic to the lead in the system.

The addition of sodium chromate reversed the situation, but as it was dangerous to continuously use such a strong oxidizing agent in rubber-lined equipment, other means had to be employed to oxidize the solution before pumping. This was done by installing a perforated lead pipe in the diluting tank and using in-blown air as a mixing and cooling agent during and after the addition of the acid. This method not only mixed the acid thoroughly, but it also reduced the temperature to 140° F. The pump then was used to transfer the acid to the pickling machine. This simple arrangement was adequate to prevent further damage to the Worthite pump, although as a safety measure, insulators subsequently were employed between the lead pipe and pump.

It was interesting to note that surfaces of the pump, which failed by corrosion in six months, were lustrous and brilliant even in the bottom of the pits. This condition had been noted in a number of other cases in which Worthite was connected to lead-lined acid systems where the life of the alloy was less than expected. It now is believed the galvanic current generated was of sufficient intensity to cause electropolishing of the alloy surfaces. This phenomenon will be discussed in more detail further in this article.

In the other case investigated where 66° Bé sulfuric acid was diluted to 25 percent, resulting in a final temperature of only 140° F., it was believed this temperature was not high enough to cause deaeration of the diluted acid. However, by carefully controlled experiments, it was observed that as the strong acid was poured into water without mechanical agitation, it descended to the bottom of the tank where it diffused laterally. At the interface between acid and water, it was noted the solution was cloudy with bubbles displaced from solution. The instantaneous temperature at this interface probably was well above the boiling point of water which would progressively remove much of the normal amount of air from solution.

With field observations of this type as a guide, laboratory investigations were made to study the effects of sulfuric acid dilution on lead and stainless steels. Using the apparatus shown in Figure 2, the recorded potential differences between a saturated calomel half-cell and lead, and a saturated calomel half-cell and Worthite were obtained with 50 percent sulfuric acid as the electrolyte at temperatures between 75° F. and 130° F. Results are shown in Figure 3.

As actual field problems were to be studied, it was of course essential to simulate these conditions in the laboratory for intelligent observation and deduction of results. The problem of 50 percent acid dilution in connection with the lead-lined diluting tank, previously described, was taken as the problem for study.

As noted by Figure 3 a correct diluting process was simulated to yield 50 percent H_2SO_4 at not more than 130° F. The acid was heated rapidly by an outside source (Bunsen burner) to simulate the heat of solution which would be obtained by carefully controlling the rate of adding acid to obtain a temperature not over 130° F. The acid then was allowed to cool, again simulating actual conditions. This procedure, as shown by Figure 3, was repeated at varying intervals to simulate the subjecting of a Worthite pump to the corrosive environment resulting from diluting several batches of acid during a day. As the acid was heated, successive readings were obtained from the apparatus shown in Figure 2, and plotted accordingly.

The apparatus (Figure 2) used to obtain data for the various curves shown herein, is described as follows:

The battery jar is equipped with a reflux condenser to maintain acid concentration, when the solution is heated by the Bunsen burner. Electrical connections are provided for

the Worthite, or other electrode, lead sheet, and calomel half-cell (center of glass top). A 300° F. thermometer and laboratory stirrer also are mounted through the cover. The Worthite, lead and calomel half-cell are connected to a switch and resistance box which contains small resistance banks calibrated with the corresponding wire leads. When these are connected into the circuit, measurements of very small current readings are made possible by obtaining the potential drop with a potentiometer. Switches shown on the box make it possible to control direction of current to record galvanic couple potentials between any two electrodes, and galvanic current flowing in the lead-alloy couple.

It is to be noted (Figure 3) that at the start of the study, the Worthite showed a very noble position due to its highly passive state from contact with air. It retained this passive or noble condition for most of the first two periods of heating and cooling of the diluted acid. Then the protective film apparently was reduced, after which the alloy rapidly lost this initial passive position, stabilizing itself at about —0.15 volt compared to a saturated calomel half-cell as zero. It is of interest to note that normal corrosion rate of Worthite in 50 percent sulfuric acid at this temperature is very low. The lead showed an initial potential with reference to a saturated calomel half-cell at about —0.35 volt. Subjected to temperature changes with time, the potential difference decreased as lead sulfate formed on the surface until it stabilized at about —0.22 volt.

It then was hypothesized from the above experiment that if 50 percent sulfuric acid was obtained by correct dilution (agitation and heating of dilution controlled so as not to produce a temperature of over 130° F.), Worthite would be cathodic to lead in a galvanic system. This is a logical deduction, since no adverse reports have been received from the field under such conditions of service.

Using the same field example, the improper dilution of sulfuric acid was simulated in the experimental apparatus and the results observed. Thus, the Worthite-lead system was subjected to 66° Bé sulfuric acid as it was poured quickly into water to yield 50 percent deaerated acid with a resulting temperature of 240° F. Readings pertaining to only the potential differences between Worthite and lead at the corresponding temperatures were obtained first. Results are shown as an average of several tests in Figure 4.

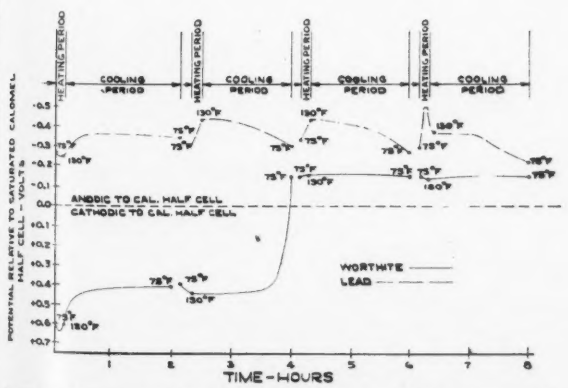


Figure 3—Potentials of Worthite and lead vs. a saturated calomel half cell in 50 percent H_2SO_4 during alternate periods of heating and cooling to 130° F. and room temperature respectively.

Thus, it is illustrated, there is a change of the relative position of lead and Worthite in 50 percent deaerated sulfuric acid. This results in the Worthite becoming anodic to the lead 4 minutes after diluting. Here, the acid temperature had dropped to 220° F. Curiously enough, as the acid continued to cool, the potential difference increased to a maximum of —0.16 volt at the corresponding temperature of 145° F. As further cooling proceeded, the potential difference decreased and finally stabilized at about —0.05 volt at room temperature. It will be shown later that this potential may be a very dangerous range in respect to the galvanic current generated. It will be understood that the curve shown in Figure 4 is a resultant of the relative potentials indicative of the respective individual positions of the Worthite and lead in the galvanic series. Consequently, in order to study the relative positions of lead and Worthite in the galvanic series in such an environment, experiments were made with concurrent readings of these potentials referred to a saturated calomel half-cell. In these experiments, the 50 percent sulfuric acid was heated more slowly over a Bunsen burner in order that a more detailed study could be made, and at the same time simulating the heat produced by improper acid diluting. The results are shown in Figure 5.

Here it is to be noted that Worthite stabilized in the cooled acid at about —0.15 volt, referred to a

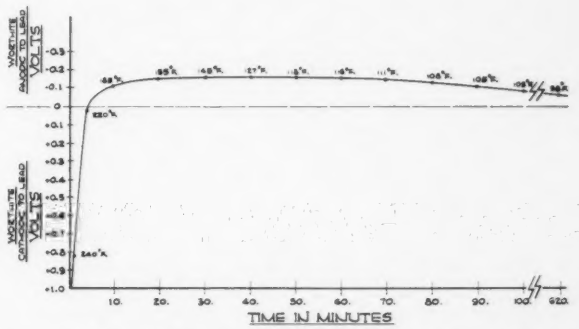


Figure 4—Potential difference between lead and Worthite at indicated temperatures developed by improper dilution of 96 percent H_2SO_4 to 50 percent H_2SO_4.

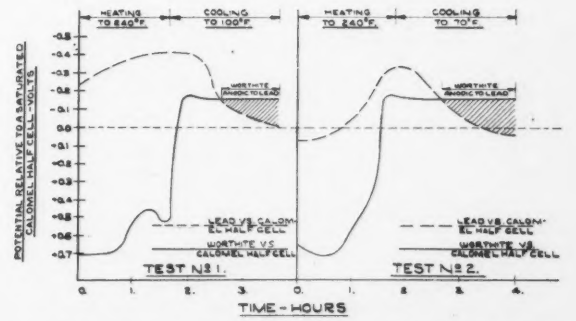


Figure 5—Potential difference referred to a calomel half cell and lead, calomel half cell and Worthite, vs. time, electrolyte 50 percent H_2SO_4 heated to 240° F. and cooled to room temperature. Two separate tests on same specimens, Worthite passivates in air between tests. Both metals became less noble in hot acid. Worthite stabilizes at —1.5 volt. Lead retains its noble sulfate coating and tends to stabilize at +0.05 volt.

saturated calomel half-cell as zero. Conversely, lead showed an initial increase in potential as the acid was heated, but as the acid cooled and as insoluble lead sulphate formed on the surface, the lead surface became more noble and stabilized at around +0.05 volt referred to a saturated calomel half-cell. Thus, in about 2½ hours exposure, Worthite became anodic to the sulfated lead surface and the picture presented to the investigators clearly indicated the exact mechanism of this phenomenon. In a system where the acid was not permitted to become reaerated, this condition could persist.

Apparently, only meager data previously has been developed to show that lead has a variable position in the galvanic series in certain conditions of exposure to sulfuric acid, as do many of the nickel-chrome and nickel-copper alloys. There are also only few references indicating that the same conditions that activate these alloys seem to passivate or ennoble lead. In the writers' opinion, this little-emphasized fact is very important, as it now is clearly indicated that the combination of lead with a large wetted area, connected with many alloys in a system involving sulfuric acid with little or no oxidizing capacity, must be considered very carefully in advance to determine the possible final relative positions of the metals in the galvanic series.

In several galvanic series noted in the literature, the various grades of ordinary stainless steel and the high chrome-nickel-molybdenum alloys are shown in two locations, one in the "passive" state near silver and the other in the "active" state above lead and near iron. It is stated further "the positions occupied may be anywhere between the extremes indicated."

The question may, therefore, arise as to just where the most "active" state may be in hot 50 percent deaerated sulfuric acid. It is well known that the halide ions cause the greatest activation of these types of alloys. Therefore, a specimen of Worthite was fully "activated" in hot hydrochloric acid and then placed in the apparatus shown in Figure 2, where it was subjected to 50 percent sulfuric acid. Readings were observed then and noted against those from a saturated calomel half-cell as the acid was heated and recooled to room temperature. The results are shown in Figure 6.

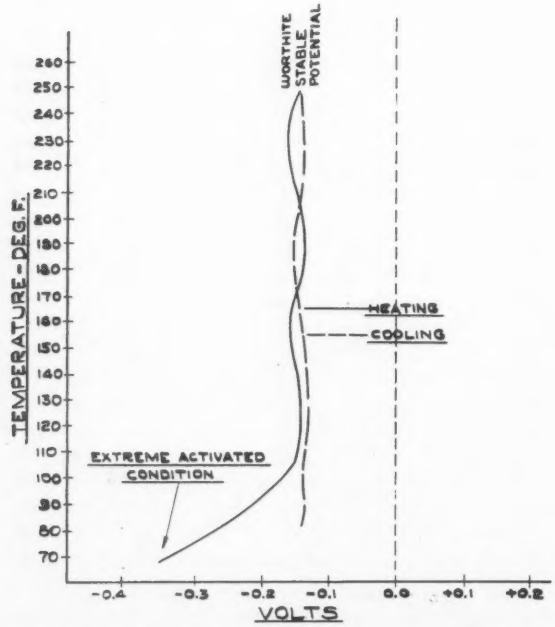


Figure 6—Potential difference between Worthite and a calomel half cell in 50 percent H_2SO_4 after Worthite previously had been fully activated in hot HCl.

This experiment indicated Worthite would not stay in the most "active" state in sulfuric acid, but stabilized at approximately —0.15 volt compared to a saturated calomel half-cell. Unfortunately, at this writing possible changes of the potential of copper under similar conditions have not been determined, but no detrimental galvanic action between copper or bronze and nickel-chrome alloys has been reported.

Other concentrations of sulfuric acid were used and the above investigation conducted accordingly. Also, to get an idea of how other alloys might act towards lead in the same environment, similar data were obtained with 18-8 stainless steel, Monel and Hastelloy "C". Results of these investigations are summarized in Figure 7, showing the ranges of potential attained with lead and other alloys in sulfuric acid against a saturated calomel half-cell arbitrarily taken as zero potential.

To get the maximum potential of lead and the minimum potential of Worthite, it was necessary to deareate the acid almost completely by boiling or by improper methods of dilution. Preliminary work indicates that in 10 percent acid there is little danger of Worthite becoming anodic to lead. However, at 30 percent concentration and higher there is a probability, in deaerated acid, that lead will become more noble and galvanic action damaging to this alloy may occur. In acid of 50 percent and lower concentrations, with normal oxidizing capacity (normal amount of air in solution), Worthite always has been recorded as cathodic to lead. This is not damaging to the lead due to the "insoluble" anode and the "large area effect."

It is important also to note that Figure 7 shows

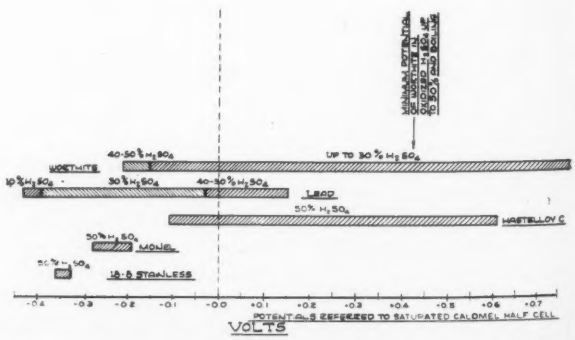


Figure 7—Range of potentials of alloys investigated subjected to H_2SO_4 at room temperature to boiling. The maximum potential of lead and the minimum potential of Worthite and Hastelloy C were obtained after the boiling point had been reached.

that all alloys investigated can be anodic to lead in certain environments involving sulfuric acid. These laboratory data are substantiated by practical evidence from field test work in the lead-lined pickling machine as recorded in one of the authors' publications.[1]

Earlier in this article it was stated it could be shown why a very small potential difference between Worthite and lead (Worthite being anodic when subjected to a 50 percent sulfuric acid galvanic system) may cause drastic corrosion of the alloy. The apparatus shown in Figure 2 was used with a sulfated-lead electrode and a partially passivated Worthite electrode. The electrolyte of 50 percent sulfuric acid was heated slowly above that temperature which would deaerate the acid and cause the Worthite to be at least partially "activated." The acid then was allowed to cool to nearly room temperature and the following readings taken:

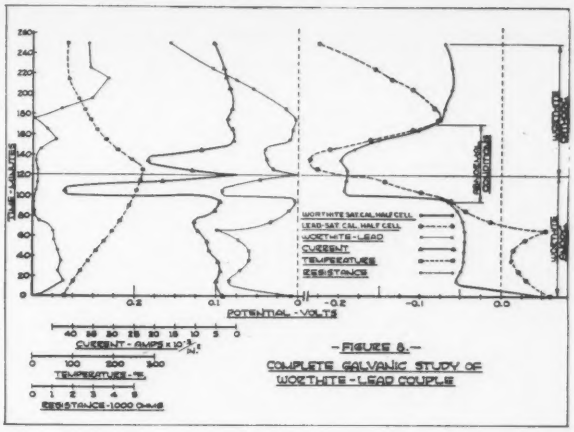
1. Potential differences between Worthite and lead
2. Potential differences between Worthite and the calomel half-cell
3. Potential differences between lead and the calomel half-cell
4. Milliamps of current between Worthite and lead.

From these readings the data were plotted as shown in Figure 8. Significant results and postulations are as follows:

Worthite quickly lost some of its passivity in less than ten minutes but remained relatively passive for 1¼ hours in a stable range of about —0.05 volt with reference to a saturated calomel half-cell. In this same period, the lead tended to retain its sulfate coating until a temperature of about 210° F. was reached after which it rapidly lost its noble characteristics. After about 1½ hours exposure when the acid had reached 240° F., the potential difference between lead and the Worthite was decreased to almost zero.

At this point, due to some unknown phenomena combined with the attained high temperature of the acid, the passive film on the Worthite apparently was destroyed or perforated, causing a sudden drop to the apparent stable region of approximately —0.18 volt. With the passive film apparently destroyed, the Worthite's high resistance to electron flow (galvanic current) was lost and a heavy surge of current occurred. Since the lead was not affected similarly and since the potential difference did not increase in proportion to the loss of cell resistance (oxide film), the galvanic current had to increase to satisfy the relationship $E = IR$ or $I = \frac{E}{R}$.

There is no doubt that if conditions were held at this point, whereby the high galvanic current continued, with the rate of electrolytic corrosion being proportional to the current flowing, the corrosion rate on Worthite would be extremely high. Fortunately, polarization occurring limits the flow of current. As this proceeds, Worthite tends to restabilize to a more passive condition, provided there is any oxidizing influence to permit re-forming of the passive film. If the condition of intermittently forming and



—FIGURE 8.—
COMPLETE GALVANIC STUDY OF WORTHITE - LEAD COUPLE

losing this film continues, it is possible the alloy will repeat this performance during each cycle, causing violent surges of galvanic current and consequent short periods of excessive corrosion. This could explain the appearance of electro-polishing previously noted in field experiences.

From the above it is indicated the theory pertaining to galvanic corrosive action of two metals as being directly related to the difference between them in the galvanic series is not necessarily valid if one of these metals is a high nickel-chrome stainless steel. The controlling factor is the stability of the passive film. It has been shown that as this film changes from an unstable passive to a stable region, depending on the corrosive conditions, the destructive current produced by the galvanic action with cathodic lead is increased rapidly, being nearly independent, except for current direction, to the potential difference of the Worthite and lead. This film breakdown in sulfuric acid can be caused by a high concentration-temperature shock or air expulsion, or loss of oxidizing capacity from other causes. After the Worthite reaches a stable value (i.e. the semi-passive film stabilizes), the current produced is related to the potential difference of the two metals, as would be expected.

It is to be noted that Worthite is able to retain an intermediate stable range in 50 percent sulfuric acid up to temperatures of approximately 210° F. while the acid is being heated, and it regains this stable range in about one hour as the acid cools from 260° F. down to 130 to 140° F. This stable range is approximately —0.05 volt referred to a saturated calomel half-cell. At any range, cathodic protection of the Worthite would be insured in contact with lead if it retained the position usually given to it in a galvanic series.

Among all tests reported herein, there could be no correlating factor which would predict the migrating characteristics in the galvanic series of the sulfated lead when subject to different corrosive conditions of sulfuric acid, temperature and concentration. Thus, under the conditions existing in the test as shown in Figure 5, the lead sulfate coating was retained when acid was cooled. In the later tests (Figure 8) this coating was removed partially and the lead became

less noble and anodic to Worthite. It is probable the galvanic current generated during the short intervals while the Worthite-lead couple current readings were taken, resulted in polarization changes that caused the variation in performance.

Only a generalized statement can be derived from the series of tests conducted in this division of the investigation. This is, that at the higher temperatures of sulfuric acid, lead takes on more noble characteristics, probably due to a lead sulfate film formation, while Worthite and most nickel-chrome alloys become less noble. The point at which Worthite loses its "stable" or practically "passive" state is probably when the temperature reaches a degree where most of the air in solution is expelled, leaving insufficient oxidizing capacity to repair the broken oxide film.

It should be noted at this point that there is an apparent reluctance for the metals to cause reversal of potential when differences of potential are decreasing slowly. In two places, as indicated on the curves in Figure 8, the potentials slowly approach zero difference, but in both cases changes occurred. When the Worthite was cathodic, this related to the cell resistance, but Worthite remained cathodic to the lead. When the Worthite was anodic, the sudden change was in the galvanic current, but Worthite remained anodic. However, when the potentials were approaching zero quite rapidly, there was no hesitance in the reversal and the respective changes in potential and current were about equal with little immediate change in the cell resistance.

It is probable that these rapid changes in galvanic current or cell resistance had some bearing on the different behavior of the lead in the test per Figure 8 than exhibited in the test per Figure 5.

From the tests conducted it can be concluded that Worthite in H_2SO_4 apparently possesses three positions in the Galvanic Series: 1. An unstable passive region (Figure 8); 2. An unstable active region (Figure 6), and 3. A stable region which seems to be dependent upon the corrosive environment as investigated (Figure 8). If this stable condition is possessed by the Worthite when galvanically coupled to lead, the latter is the controlling influence on current flow direction, as its galvanic position is very erratic (Figure 5).

The passive film on Worthite is of major consideration, being related to the above three galvanic positions. If it is considered as an oxide film, it has a reluctance to reduce and assume a less noble galvanic position. As the corrosive environment becomes more extreme, the reduction occurs in abrupt breaks (Figure 8), producing current surges of such relative high magnitude (42×10^{-5} amps/in^2) that a destructive galvanic corrosive action would occur when coupled to a large area of cathodic lead.

It is apparent also (Figure 8) that as the corrosive environment becomes less extreme, the protective film that forms causes a return to the stable position respective to this type of environment. Thus, if the lead retains a semblance of normalcy with its galvanic position (approximately —0.3 volt relative to a saturated calomel half-cell, Figure 3), galvanic corrosion of the alloy would not continue necessarily. But with certain specialized conditions, as reported, there is no guarantee of this normalcy, with actual current directional tests being the best means for determining in advance what materials should be used, or whether conditions should be changed. It is believed these incomplete and perhaps inconclusive series of experiments have given an explanation why certain failures have occurred when alloys are connected to large wetted areas of lead in certain sulfuric acid environments. At least it is known now where trouble can be expected and, therefore, provision can be made usually in advance to avoid the probable failure of the alloy equipment in such environments.

As previously stated, the trouble can be avoided by keeping the alloy in a more passive condition by adding an oxidizing element such as sodium chromate, ferric or copper sulfate, or by reaeration. Where such additions or procedures are not practical or economical, insulating the alloy equipment for metallic contact with lead may be the best solution.

The knowledge thus far obtained now is being used to correlate laboratory investigation with industrial application, and the results so far are very encouraging. Galvanic corrosion tests can be made much more informative by the procedure described in this paper, as the true analysis of the relative potentials of two metals can be pictured and recorded. It is hoped that other investigators will study these special conditions in greater detail and develop more data on alloy-lead systems as well as other systems involving other metals and other electrolytes.

Acknowledgments

Acknowledgment for advice in this experimental work and assistance in preparing this article is given to: F. L. LaQue and Dr. W. A. Wesley, International Nickel Co.; Dr. M. H. Brown, Experimental Station, E. I. du Pont de Nemours Co.; and Paul Carr, Worthington Pump & Machinery Corp.

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TECHNICAL PAPERS PROCEDURE

All papers submitted for publication in CORROSION are reviewed by the Editorial Review Committee, or specialists selected by that committee to review the papers. Suggestions of reviewers as to desirable additions or revisions are submitted to the author, who is given the opportunity to make the suggested changes. The paper in final form is accepted or rejected according to the judgment of the committee and the Editor of CORROSION. When the author can substantiate his viewpoint and prefers not to follow the suggestions of the reviewer and the overall paper merits publication, the author's wishes are followed.

A Geographic Study of Deposits and Corrosion*

By DR. F. N. ALQUIST

THE problem to be solved in this article is: "How does the composition of water-formed deposits vary among plants located in different geographical areas?" The United States Geological Survey has made many studies of industrial waters.[1] A report made in 1934 shows a map giving hardness data for the entire country (Figure 1). The Dow Chemical Company's work on the X-ray study of deposits found in operating equipment over the last ten years shows that the composition of deposits is modified by the use of water treatment and by corrosion phenomena. The value of water treatment to decrease deposits and reduce corrosion is well recognized by industries whose equipment is discussed. The data to be used will be based on 143 samples of deposits taken from boilers, condensers and pipe lines. These samples were taken over an area of ten industrially important states. Twenty practical cases are cited in which the deposits were removed by inhibited hydrochloric acid. The drained solvents from these cases were studied by the methods of quantitative analysis and calculation to find the extent of operational corrosion and deposition in operating equipment.

DR. F. N. ALQUIST

Research Chemist, Organic Research Division, The Dow Chemical Company, Midland, Mich. Dr. Alquist, successively instructor in chemistry at Rennselaer Polytechnic Institute, St. Lawrence University and Purdue University, from which he received his Ph.D. in 1930, has been research chemist in Dow Company laboratories since then. His field includes metal corrosion inhibitors, corrosion problems, water type deposits and oil field chemical problems.

To avoid confusion in terminology, this paper adopts the definitions and sampling practice in "The Tentative Recommended Practice for Field Sampling of Water Deposits," A.S.T.M. D887-36T, issued in 1946. For convenience, the definitions are quoted below followed by the sampling practice.

"(a) 'Water Formed Deposits' is any accumulation of insoluble material derived from water or formed by the reaction of water upon surfaces in contact with the water.

"(b) 'Scale' is a deposit formed from a solution directly in place upon a confining surface.

"(c) 'Sludge' is a water-formed sedimentary deposit.

"(d) 'Corrosion Product' is a result of chemical or electrochemical reaction between a metal and its environment.

"(e) 'Biological Deposits' are water formed deposits of biological organisms or the products of their life processes.

"SAMPLING PRACTICE, the same should be removed in such a manner that it remains as nearly as possible in the existing state. Care should be exercised to obtain pieces sufficiently large so that individual layers can be studied and analyzed. When the deposit cannot be separated cleanly from the underlying surfaces, or when a significant change in composition of the deposit adjacent to underlying surface is suspected, a portion of the surface with the deposit intact shall be removed, if practical considerations permit.

"A sample of sufficient size for the intended examination shall be removed.[2] The quantity of sample removed may be limited by the amount of deposit available in the desired region. In general, 100 grams will suffice for rather complete tests, 10 grams for routine chemical analysis, and even a very small amount for study by microscopic, X-ray diffraction, or spectroscopic methods."

A. Analysis of Water-Formed Deposits.

The need of careful sampling can be shown by a study of Figure 2. This shows variation of deposits over adjacent area of a boiler tube.

The deposits tabulated after chemical classification on a geographical basis were selected at random from the files of thousands of samples analyzed by the Dow Chemical Company over a ten-year period in connection with the industrial acid cleaning of industrial equipment by its subsidiary, Dowell, Inc. The states of New York, New Jersey, Pennsylvania, Ohio, Indiana, Michigan, Illinois, Wisconsin, Louisiana and Texas were selected because of their industrial importance. The deposits were from heat exchange equipment used in the following industries: Automotive, chemical distilling, oil refining, paper, rubber, steel and metal, utilities and general manufacturing.

The deposits in Tables I through VI were analyzed by diffraction methods. This procedure is basically that of Hull with the contribution of Hanawalt, Rinn and Frevel. In June 1947, The American Society of

* A Paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

Testing Material formulated a "Proposed Tentative Recommended Practice for Application of X-ray Diffraction Methods to Water-Formed Deposits."[4]

The Tables I through VI show the state, city, industry, type of equipment and quantitative X-ray diffraction analysis of deposit.

In the 143 deposits over a ten-state area, there are a total of 427 analytical items of which many reoccur in all the deposits studied. These recurring items or constituents can be classified in the following chemical groups or compounds:

Carbonates of calcium or magnesium or mixed like dolomite—$CaCO_3$ or $CaMg(CO_3)_2$

Calcium sulfate—$CaSO_4$

Calcium hydroxyapatite—$Ca_{10}(OH)_2(PO_4)_6$ or Phosphates

Magnesium hydroxide—$Ng(OH)_2$

Oxides of iron—FeO, Fe_2O_3, Fe_3O_4, alpha-FeOOH, gamma-FeOOH

Copper—Cu

Silicon compound—SiO_2, $Mg_3Si_2O_7 \cdot 2H_2O$, alkali; alkaline earth silicates like $NaAlSi_2O_6 \cdot H_2O$ or $CaSiO_3$, more complex silicates.

Classification	% of Deposits Containing	Number of Occurrences
Carbonates	14.5%	62
Sulfates	5.5%	24
Phosphates	14.0%	59
Hydroxides	2.7%	12
Oxides of iron	27.0%	158
Copper	3.5%	15
Silicon compounds	20.6%	90
Miscellaneous	2.2%	9
	100.0%	427

Boiler Deposits Containing Phosphates.

Table I lists the deposits that contain phosphates, mixed with iron oxides, hydroxides, silicon compounds, carbonates and sulfates but no copper. These mixed types of deposits are very common. The phosphate content varies from 5 percent to 95 percent in 43 samples. The silicon compounds content varies from 10 percent to 70 percent in 31 deposits. The hydroxide content varies from 5 percent to 75 percent in 5 deposits. The carbonate content varies from 10 percent to 60 percent. The sulfates vary from 20 percent to 25 percent in 4 deposits. The number containing iron oxides is 25 out of 43. The iron oxide content varies from 5 percent to 45 percent. It is the author's belief that properly taken samples would show iron oxides in all cases of deposits from operating surface of boilers. It is to be noted that copper-free deposits containing phosphates are found in all ten states.

Boiler Deposits Containing Silicon Compounds but Free of Copper and Phosphate.

Table II. The copper-containing deposits and phosphate-containing deposits which also include silicon compounds are tabulated in Tables II and III. Table II lists deposits which contain no copper or phosphates. The percentage of silicon compounds of 24 deposits in Table II varies from 5 percent to 75 percent. The carbonate content varies from 5 percent to 90 percent in 18 deposits. The sulfate content varies from 5 percent to 85 percent in 6 deposits. The hydroxide content varies from 10 percent to 35 percent in 6 deposits. Iron oxides are found in 9 out of 24 deposits; the variation in percentage is from 5 per cent to 75 percent. These types of deposits are found in nine of the ten states.

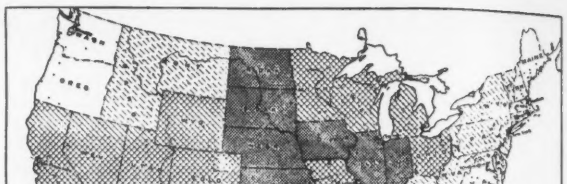

Figure 1—Weighted average hardness, by states, of water furnished in 1932 by public supply systems in over 600 cities in the United States.

Boiler Deposits Containing Copper.

Table III. Copper is carried from the corrosion of turbine condensers into the boiler by the return condensate, so deposits containing copper are classified separately in Table III. The amount of copper varies from 5 percent to 25 percent in 15 deposits. The other constituents are oxides of iron, silicon compounds and phosphates. Only three of the fifteen deposits consist mainly of $Ca_{10}(OH)_2(PO_4)_6$. Silicon compounds are major constituents in two deposits. In six deposits, oxides of iron are the major constituents. The other deposits are mixtures of these constituents. These types of deposits were found in eight of the ten states.

Boiler Deposits Containing Sulfates.

Table IV. Deposits containing calcium sulphate contain also calcium carbonate, hydroxides and oxides of iron. The sulfates vary from 10 percent to 80 percent in 9 deposits. The carbonates vary from 10 percent to 90 percent in 8 deposits. The hydroxides vary from 10 percent to 60 percent in 3 deposits. The iron oxides vary from 10 percent to 45 percent in 3 deposits. Sulfates are found also in Tables I and II

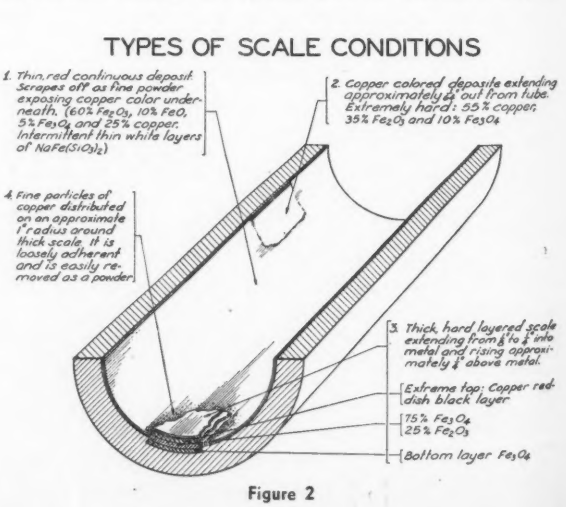
TYPES OF SCALE CONDITIONS
1. Thin, red continuous deposit. Scrapes off as fine powder exposing copper color underneath. (60% Fe_2O_3, 10% FeO, 5% Fe_3O_4 and 25% copper. Intermittent thin white layers of $NaFe(SiO_3)_2$)
2. Copper colored deposits extending approximately ¼" out from tube. Extremely hard: 55% copper, 35% Fe_2O_3 and 10% Fe_3O_4
4. Fine particles of copper distributed on an approximate ½" radius around thick scale. It is loosely adherent and is easily removed as a powder.
3. Thick, hard layered scale extending from ⅛ to ¼ into metal and rising approximately ¼" above metal.
Extreme top: Copper reddish black layer
75% Fe_3O_4
25% Fe_2O_3
Bottom layer Fe_3O_4

Figure 2

which include 10 deposits with this compound. Sulfates were found in nine of the ten states.

Condenser Deposits.

Table V. In the 23 condenser deposits involving nine of the ten states, water-borne deposits consisting mainly of carbonates appear twelve times in Table V. Silica in the form of SiO_2 occurs in amounts of 5 percent to 30 percent in 11 of the 23 examples. Oxides of iron are the main constituents in 13 of the 23 deposits, the percentages varying from 10 percent to 100 percent. Phosphates and sulfates are found occasionally.

Pipe Line Deposits.

Table VI. In 34 pipe line deposits, oxides of iron predominate in 22 of the cases shown in Table VI covering ten states. Calcium carbonate is the main constituent in 8 examples. Silicon compounds occur in 7 deposits. Phosphates occur in 4 cases and calcium sulfate twice. It appears that corrosion is the main factor of the pipe line deposits. Water-borne or water-treatment products are the other factors in lessening pipe line capacity. However, examples of deposits and corrosion occurring simultaneously are the more generally occurring phenomena.

B. Theory to Find the Extent of Operational Corrosion and Deposition.

It has been shown that deposits from boilers, condensers and pipe line deposits contain corrosion products. Methods to find the extent of corrosion of operating equipment are needed. The method suggested is the use of quantitative chemical analysis of "drain acid." This method not only gives the extent of corrosion but by knowing the X-ray data on composition of deposits enables the calculation of amounts of deposits.

"Drain acid," as the term is used in this discussion, means the solvent which has been used to remove the deposits and corrosion products when chemical methods are used. The use of inhibited hydrochloric acid to remove deposits and corrosion products has been widely used for a number of years. The amount of acid reacted can be determined by titration with alkali using an indicator but this procedure does not tell either the amount of deposits or corrosion products. A simple deposit of iron oxide and calcium carbonate after removal with inhibited acid gives a solution containing calcium chloride and ferrous chloride. This "drain acid" can be analyzed for calcium and iron and applying the theory suggested one can calculate the amount of calcium carbonate and iron oxide in the deposit.

To find the extent of corrosion of operating equipment, it is necessary to make use of data from two recent publications that relate to the use of inhibited hydrochloric acid for removing deposits.

Four figures from a paper entitled "Action of Inhibited Hydrochloric Acid on Boiler Tubes" will be briefly discussed.

"The inhibitor is the most important agent among those to be selected before acid-cleaning any equipment. There are many inhibitors on the market and each is more or less efficient in inhibiting the action of acid on the metal. However, all inhibitors are not equally effective. This point is shown in Figure 3 which graphs the corrosion rates of SA 192 boiler tubes in 5 percent and 10 percent hydrochloric acid solutions inhibited with three inhibitors. This graph also shows that metal corrosion by inhibited acid increases with rise in temperature or concentration of the inhibited hydrochloric acid.

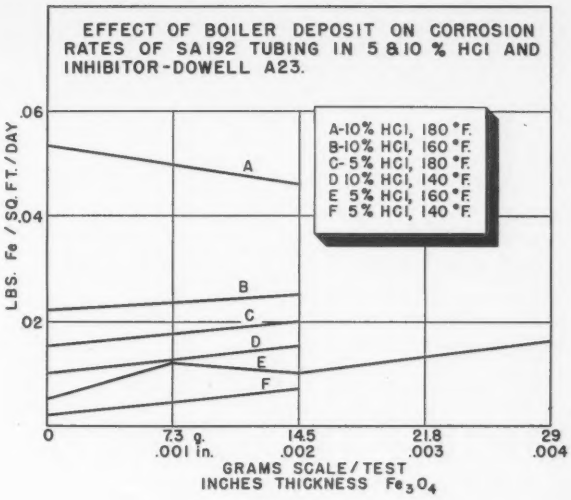
EFFECT OF BOILER DEPOSIT ON CORROSION RATES OF SA192 TUBING IN 5 & 10 % HCl AND INHIBITOR-DOWELL A23.
A-10% HCl, 180 °F.
B-10% HCl, 160 °F.
C-5% HCl, 180 °F.
D 10% HCl, 140 °F.
E 5% HCl, 160 °F.
F 5% HCl, 140 °F.
LBS. Fe / SQ. FT. / DAY
.06
.04
.02
0
7.3 g. .001 in.
14.5 .002
21.8 .003
29 .004
GRAMS SCALE / TEST
INCHES THICKNESS Fe_3O_4

Figure 3

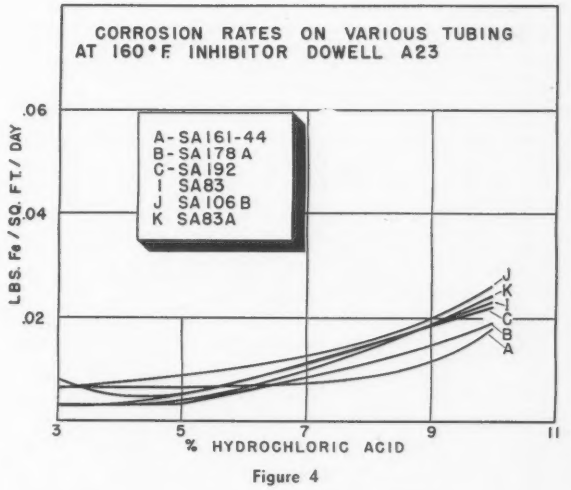

Figure 4

"The six different types of boiler tubes treated, whose specifications are given in Table 7, were equally well protected by the A-23 inhibitor. Figure 4 shows the corrosion rates of the tubes in 3 percent to 10 percent hydrochloric acid with best inhibitor A-23 at 160° F. The average corrosion rate of these six tubes, under the most severe conditions of 160° F. and 10 percent hydrochloric acid, was only 0.022 lb. per sq. ft. per day.

"Figure 5 shows the effect of temperature on the corrosion rate of the various boiler tubes in 5 percent hydrochloric acid inhibited with the same inhibitor. At 180° F. the corrosion rates vary somewhat, show-

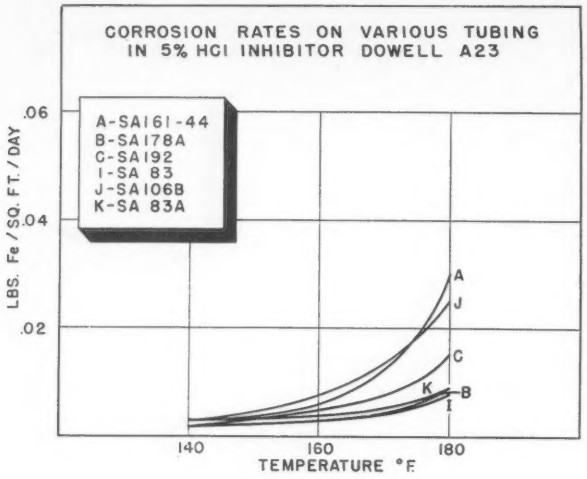

Figure 5

Chemical Specifications of Selected Boiler Tubing Constituents, Percentage by Weight

Specification Designation	C	Mn	P (Max.)	S (Max.)	Si
SA 83	0.08 to 0.18	0.3 to 0.6	0.04	0.045	.....
SA 83A	0.08 to 0.18	0.3 to 0.6	0.04	0.045	.....
SA 106B	0.35 (max.)	0.35 to 1.00	0.04	0.06	0.10 (min.)
SA 161	0.10 to 0.20	0.30 to 0.60	0.04	0.04	0.10-0.50
SA 178	0.08 to 0.18	0.3 to 0.6	0.04	0.045	.....
SA 192	0.09 to 0.18	0.3 to 0.6	0.04	0.045	0.25 (max.)

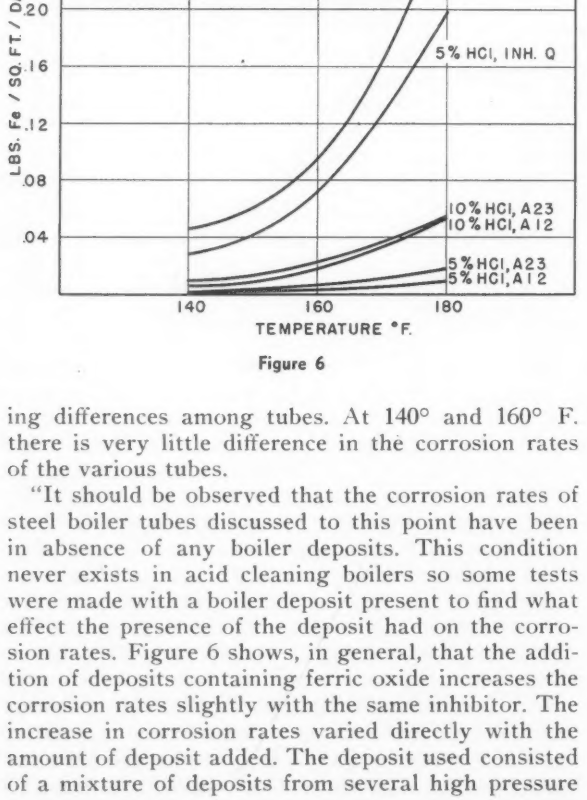

Figure 6

ing differences among tubes. At 140° and 160° F. there is very little difference in the corrosion rates of the various tubes.

"It should be observed that the corrosion rates of steel boiler tubes discussed to this point have been in absence of any boiler deposits. This condition never exists in acid cleaning boilers so some tests were made with a boiler deposit present to find what effect the presence of the deposit had on the corrosion rates. Figure 6 shows, in general, that the addition of deposits containing ferric oxide increases the corrosion rates slightly with the same inhibitor. The increase in corrosion rates varied directly with the amount of deposit added. The deposit used consisted of a mixture of deposits from several high pressure boilers, which had been ground to pass through a 30-mesh screen and mixed thoroughly.

"X-ray analysis of the deposit showed it to contain 50 percent Fe_3O_4, 20 percent sodium ferrous phosphate, $Ca_{10}(OH)_2(PO_4)_6$, 10 percent $Mg_3(PO_4)_2$ $Mg(OH)_2$ and a trace of metallic copper. A partial chemical analysis showed it to contain 36.6 percent iron and 1.13 percent copper."

It will be necessary to use seven chemical reactions with the accompanying explanations from a second recent paper by F. N. Alquist and J. L. Wasco entitled, "Ferric Ion Corrosion During Acid Cleaning."[3]

"Most steel heat-exchange equipment using water or steam becomes fouled with iron oxides on the water side of the unit. Magnetic iron oxide, Fe_3O_4, is a corrosion product in high pressure boilers. It is formed by the water dissociation reaction:

$$3\ Fe + 4\ H_2O_4 \rightarrow Fe_3O_4 + 4H_2 \quad (1)$$

"Red iron oxide, Fe_2O_3, is formed in any boiler or heat exchanger unit which uses water which has not been completely deareated:

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3 \quad (2)$$

"During the acid cleaning of a heat exchanger unit, these iron oxides are dissolved, forming ferric ion salts:

$$2\ Fe_3O_4 + 8\ HCl \rightarrow 2\ FeCl_3 + FeCl_2 + 4\ H_2O \quad (3)$$

$$Fe_2O_3 + 6\ HCl \rightarrow 2\ FeCl_3 + 3\ H_2O \quad (4)$$

"However, the drain acid solutions give no test for ferric ion; all of the iron present is in the ferrous state.

"There are two reactions which reduce the ferric ion to ferrous:

$$2\ FeCl_3 + \text{Nascent Hydrogen} \rightarrow 2\ FeCl_2 + 2\ HCl \quad (5)$$

$$2\ FeCl_3 + Fe \rightarrow 3\ FeCl_2 \quad (6)$$

"The hydrogen in nascent state is produced by reaction of iron with acid:

$$Fe + 2\ HCl \rightarrow 2(H) \text{ or } H_2 + FeCl_2 \quad (7)$$

"Laboratory tests have proved that these reactions take place simultaneously during acid cleaning. Reaction (5) was shown to occur by corrosion tests in which hydrogen evolution measurements were made. The amount of hydrogen produced by the action of inhibited acid on steel is materially reduced when a ferric salt or ferric oxide is added to the acid. Tests have shown that as much as a 50 percent reduction in hydrogen evolution can be effected by the presence of a ferric salt.

"Equation (6) is shown to be true by the increase in corrosion of steel in inhibited acid when ferric ions are present. From reactions (5), (6) and (7), it is obvious that the economic loss is metallic iron.

"The acid corrosion inhibitor which protects the metal from attack by acid has no restraining effect on the corrosion of the metal by the ferric ions. The extent of the ferric ion corrosion is dependent entirely on the amount of ferric oxides dissolved. The present methods of acid cleaning are controlled so that the sum of the acid corrosion and the ferric ion corrosion is not excessive."

C. Field Studies.

1. Field Study No. 1

The boiler was a 1400-pound pressure boiler with a steaming rate of 400,000 pounds per hour. It was

located in Illinois and water treatment was supervised by the utility company chemists, having a competent water treating firm as a consultant.

The first step in obtaining data was to secure samples from the boiler. This was done co-operatively by the operators' chemist, the water consultants and a Dowell field engineer. An X-ray analysis made in Dow laboratories gave results as follows:

	Iron Oxide Fe_3O_4	Hydroxy-apatite $Ca_{10}(OH)_2(PO_4)_6$	Copper Cu
Tube 1	45%	50%	5%
Tube 3	50%	45%	5%
Tube 5	40%	55%	5%
Tube 7*	20%	55%	5%

* In tube 7 there was also 20% of an unidentified crystalline material which contained calcium, magnesium and phosphate.

The next step to find the thickness of the deposits after this boiler had been acid-cleaned was to obtain and chemically analyze the drain acid samples. The data and calculations from these operations are found in Table VIII.

After the boiler was treated, tubes selected at random were turbined. A few grams of residual deposit was obtained in this way showing 99 percent cleanliness. The total volume of Fe_3O_4 was 1.6 cubic feet. The surface area being 21,000 square feet, the over-all thickness of Fe_3O_4 was 0.0009 inch. The over-all average thickness of hydroxy apatite was 0.0012 inch.

2. Field Study 2 and 3

In Indiana, two boilers were acid cleaned for a steel company. The first boiler contained 4480 pounds of hydroxy apatite, 1878 pounds of magnesium silicate and 402 of iron oxide. The second boiler contained 4659 pounds of hydroxy apatite, 1874 pounds of magnesium silicate and 356 pounds of iron oxide. This data was calculated from the analysis of drain acid. These two boilers in the same power plant, using the same water, were alike and operated for the same length of time before the acid cleaning. The visual inspection and turbining showed 99 percent cleanliness. The surface area of the boiler was 12,000 square feet. The cubic feet of iron oxide was 1.26. The over-all thickness of iron oxide was 0.0018 inch.

3. Field Study 4 and 5

In Illinois, two twin locomotives were cleaned for a railroad. From the first locomotive, 944 pounds of calcium carbonate, 141 pounds of magnesium silicate and 183 pounds of iron oxide were removed. From the second locomotive, 865 pounds of calcium carbonate, 607 pounds of magnesium silicate and 189 pounds of iron oxide. Figures 7 and 8 show the changes in acid concentration, iron, calcium and magnesium from sample taken during the treatments. Inspection in the shop after dismantling showed the cleaning to be very satisfactory. The cubic feet of iron oxide removed was 0.6. Surface area in these cases is unknown and further calculations cannot be made.

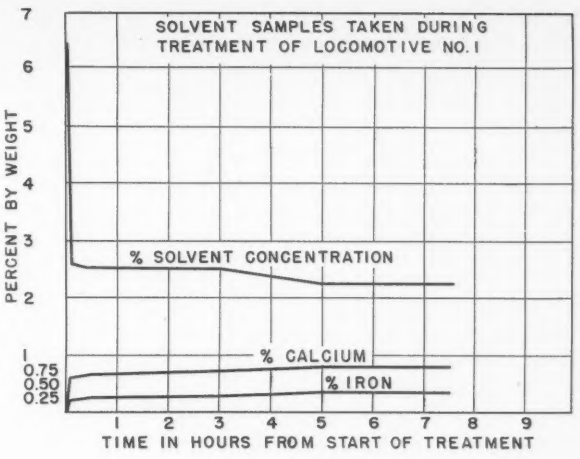
SOLVENT SAMPLES TAKEN DURING TREATMENT OF LOCOMOTIVE NO. 1
PERCENT BY WEIGHT
% SOLVENT CONCENTRATION
% CALCIUM
% IRON
TIME IN HOURS FROM START OF TREATMENT

Figure 7

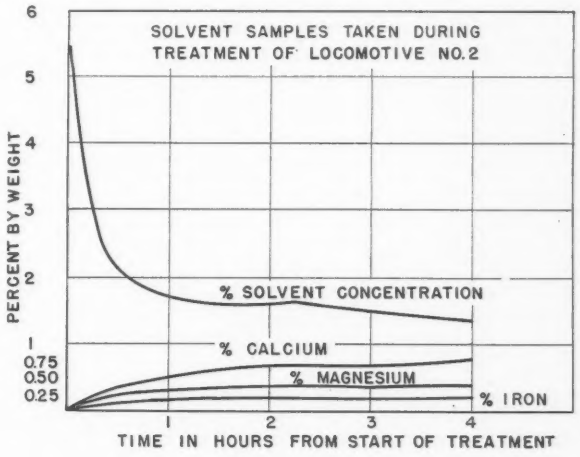
SOLVENT SAMPLES TAKEN DURING TREATMENT OF LOCOMOTIVE NO. 2
PERCENT BY WEIGHT
% SOLVENT CONCENTRATION
% CALCIUM
% MAGNESIUM
% IRON
TIME IN HOURS FROM START OF TREATMENT

Figure 8

4. Field Study 6

In Ohio, a boiler for a utility was acid cleaned. This boiler operated at 875 p.s.i. and had a rating of 253,000 pounds of steam per hour. The deposits removed consisted of 248 pounds of magnesium silicate, 341 pounds of hydroxy apatite and 822 pounds of iron oxide. The density of the deposit was 3.12, the total area was 28,000 sq. ft. and 1411 pounds of deposits were removed. Average thickness of the deposits was 0.0031 inch before treating with inhibited acid. Total iron oxide removed was 2.6 cubic feet. Thickness of iron oxide was 0.0011. Thickness of other constituents was 0.002 inch.

5. Field Studies 7 Through 20

Corrosion data on 14 utility boilers operated on the eastern seaboard at different locations are tabulated in a self-explanatory manner in Table IX. When it is realized that the 14 boilers were made at different times, and that the metal in each is different, the average thickness of iron oxide of 0.001 inch plus

or minus 0.0004 inch shows surprising consistency.

Field data on boilers 17 and 19 show higher iron oxide thickness of 0.0017 and 0.0031 inch. These thicknesses were probably a consequence of longer operating time before cleaning.

In boilers under discussion in field studies 7 through 20 an equal or greater thickness of non-corrosion deposits were present, mostly hydroxy apatite, $Ca_{10}(OH)_2(PO_4)_6$ and lesser amounts of silicon compounds.

The amount of iron removed from boilers in Table IX, whether resulting from iron oxide, acid action or ferric iron corrosion, is an economic loss of metal. The assumptions made in the table for calculations are dependent on equations and graphs in Part B of paper. After the deposit is removed the hot inhibited acid is acting on the metal surface, therefore, 0.015 pound per square foot loss is used to calculate the acid effect. Laboratory data indicates that nascent hydrogen reduces at least 50 percent of the ferric iron to ferrous and only ferrous iron is found in the drain acid from the treatment of the boiler. The fact that higher corrosion rates are indicated in the graph when deposits are added in tests on boiler metal shows that boiler iron may also reduce the ferric ion to ferrous ion. Further research on the system iron oxides—boiler metal—inhibited acid may allow better estimation of iron oxide thickness in operating boilers.

Conclusions

The composition of deposits is not a matter of geographical location because of water treatment and corrosion effects.

The foregoing statement is based on data on deposits from one hundred boilers, twenty-three condensers and thirty-four pipe line deposits over an area of ten states.

Removal of deposits with inhibited hydrochloric acid and calculations from chemical analysis of drain acids allows estimation of the over-all average thickness of deposits and corrosion products.

The operational corrosion of several boilers shows that over-all average thickness of iron oxide is 0.001 inch plus or minus 0.0004 inch.

Research methods are outlined which enable operators to find the extent of corrosion and deposition in operating equipment due to the action of industrial waters.

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1. The Industrial Utility of the Public Water Supplies in the United States, 1932 U. S. Geological Survey Water Supply Paper 658, 1934. 135 pages.
2. J. L. Wasco and F. N. Alquist, Acid Cleaning Boilers. *Corrosion*, **4**, No. 1, 28-30 (1948) Jan.
3. F. N. Alquist, J. L. Wasco and H. A. Robinson, Ferric Iron Corrosion During Acid Cleaning. *Corrosion*, **3**, No. 10, 482-487 (1947) Oct.

TABLE I

Boiler Deposits Containing Phosphates

Buffalo, New York	60% $Ca_{10}(OH)_2(PO_4)_6$ 10% Fe_2O_3 20% Fe_3O_4 10% $Mg_3Si_2O_7 \cdot 2H_2O$	Utility
New York City, New York	40% $Ca_{10}(OH)_2(PO_4)_6$ 25% Fe_3O_4 20% Fe_2O_3 15% $Mg_3Si_2O_7 \cdot 2H_2O$	Utility
New York City, New York	70% $Ca_{10}(OH)_2(PO_4)_6$ 5% Fe_3O_4 25% $Mg_3Si_2O_7 \cdot 2H_2O$	Utility
Olean, New York	35% $Ca_{10}(OH)_2(PO_4)_6$ 60% $CaCO_3$ 5% $CaSO_4$	Manufacturing
Parlin, New Jersey	40% $Ca_{10}(OH)_2(PO_4)_6$ 30% Fe_2O_3 30% $5CaO \cdot 5SiO_2 \cdot H_2O$	Chemical
Somerville, New Jersey	55% $Ca_{10}(OH)_2(PO_4)_6$ 15% Fe_3O_4 10% Fe_2O_3 20% $Mg_3Si_2O_7 \cdot 2H_2O$	Manufacturing
Bethlehem, Pennsylvania	80% $Ca_{10}(OH)_2(PO_4)_6$ 20% Fe_3O_4	Steel
Lancaster, Pennsylvania	30% $Ca_{10}(OH)_2(PO_4)_6$ 30% Fe_3O_4 15% Fe_2O_3 10% $Ca\ CO_3$	Building
Philadelphia, Pennsylvania	70% $Ca_{10}(OH)_2(PO_4)_6$ 15% Fe_2O_3 15% $Mg_3Si_2O_7 \cdot 2H_2O$	Railroad
Philadelphia, Pennsylvania	80% $Ca_{10}(OH)_2(PO_4)_6$ 10% $CaCO_3$ 10% $Mg_3Si_2O_7 \cdot 2H_2O$	Refinery
Ashtabula, Ohio	60% $Ca_{10}(OH)_2(PO_4)_6$ 40% $Mg_3Si_2O_7 \cdot 2H_2O$	Ship
Circlesville, Ohio	50% $Ca_{10}(OH)_2(PO_4)_6$ 50% $Mg_3Si_2O_7 \cdot 2H_2O$	Metal
Cleveland, Ohio	95% $Ca_{10}(OH)_2(PO_4)_6$ 5% Fe_3O_4	Steel
Cleveland, Ohio	70% $Ca_{10}(OH)_2(PO_4)_6$ 10% Fe_2O_3 10% $CaCO_3$ 10% $4CaO \cdot MgO \cdot 6SiO_2 \cdot H_2O$	Refinery
Columbus, Ohio	20% $Ca_{10}(OH)_2(PO_4)_6$ 10% Fe_2O_3 10% $Mg(OH)_2$ 20% $CaCO_3$ 10% $CaSiO_3 \cdot H_2O$ 30% $Mg_3Si_2O_7 \cdot 2H_2O$	Food
St. Marys, Ohio	65% $Ca_{10}(OH)_2(PO_4)_6$ 5% $Fe\ _3O_4$ 15% $Mg_3(PO_4)_2 \cdot Mg(OH)_2$ 15% $Mg_3Si_2O_7 \cdot 2H_2O$	Paper
Toledo, Ohio	70% $Ca_{10}(OH)_2(PO_4)_6$ 5% Fe_2O_3 10% Fe_3O_4 15% $Mg_3Si_2O_7 \cdot 2H_2O$	Utility
Dunkirk, Indiana	40% $Ca_{10}(OH)_2(PO_4)_6$ 40% $CaCO_3$ 20% $Mg_3Si_2O_7 \cdot 2H_2O$	Food
Lawrenceburg, Indiana	75% $Ca_{10}(OH)_2(PO_4)_6$ 25% $Na_8Al_6Si_6O_{24}Cl_2$	Distillery
Muncie, Indiana	40% $Ca_{10}(OH)_2(PO_4)_6$ 40% $CaCO_3$ 15% $Mg_3Si_2O_7 \cdot 2H_2O$ 5% $Mg(OH)_2$	
Adrian Michigan	25% $Ca_{10}(OH)_2(PO_4)_6$ 10% Fe_2O_3 45% Fe_3O_4 20% $CaCO_3$	Metal
Ann Arbor, Michigan	5% $Ca_{10}(OH)_2(PO_4)_6$ 25% $Mg(OH)_2$ 50% $CaCO_3$ 20% $Mg_3Si_2O_7 \cdot 2H_2O$	Manufacturing
Grand Rapids, Michigan	35% $Ca_{10}(OH)_2(PO_4)_6$ 50% $CaCo_3$ 15% $Mg_3Si_2O_7 \cdot 2H_2O$	Food
Kalamazoo, Michigan	30% $Ca_{10}(OH)_2(PO_4)_6$ 10% Fe_2O_3 45% Fe_3O_4 15% $Mg_3Si_2O_7 \cdot 2H_2O$	Paper
Kalamazoo, Michigan	80% $Ca_{10}(OH)_2(PO_4)_6$ 20% Fe_2O_3	Paper
Milwaukee, Wisconsin	15% $Ca_{10}(OH)_2(PO_4)_6$ 5% Fe_2O_3 60% $CaCO_3$ 20% $Mg_3Si_2O_7 \cdot 2H_2O$	Steamer

Neenah, Wisconsin	55% $Ca_{10}(OH)_2(PO_4)_6$ 35% Fe_2O_3 10% $CaCO_3$	Paper
Chicago, Illinois	45% $Ca_{10}(OH)_2(PO_4)_6$ 5% $Mg(OH)_2$ 50% $CaCO_3$	Manufacturing
Chicago, Illinois	20% $Ca_{10}(OH)_2(PO_4)_6$ 60% $CaCO_3$ 20% $Mg_3Si_2O_7 \cdot 2H_2O$	Food
Chicago, Illinois	50% $Ca_{10}(OH)_2(PO_4)_6$ 10% $CaCO_3$ 40% $Mg_3Si_2O_7 \cdot 2H_2O$	Metal
Chicago, Illinois	40% $Ca_{10}(OH)_2(PO_4)_6$ 5% Fe_2O_3 45% $CaCO_3$ 10% $Mg_3Si_2O_7 \cdot 2H_2O$	Utility
Chicago, Illinois	30% $Ca_{10}(OH)_2(PO_4)_6$ 50% Fe_3O_4 20% Fe_2O_3	Utility
Peoria, Illinois	10% $Ca_{10}(OH)_2(PO_4)_6$ 75% $Mg(OH)_2$ 10% $CaCO_3$ 5% Fe_2O_3	Distillery
Riverdale, Illinois	80% $Ca_{10}(OH)_2(PO_4)_6$ 20% $Mg_3Si_2O_7 \cdot 2H_2O$	Steel
Wood River, Illinois	60% $Ca_{10}(OH)_2(PO_4)_6$ 40% $5CaSiO_3$	Refinery
Wood River, Illinois	60% $Ca_{10}(OH)_2(PO_4)_6$ 30% Fe_3O_4 10% $Mg_3Si_2O_7 \cdot 2H_2O$	Refinery
Baton Rouge, Louisiana	70% $Ca_{10}(OH)_2(PO_4)_6$ 20% Fe_3O_4 10% Fe_2O_3	Refinery
Baton Rouge, Louisiana	50% $Ca_{10}(OH)_2(PO_4)_6$ 30% Fe_2O_3 20% $Na\ Fe(SiO_3)_2$	Refinery
Lafayette, Louisiana	30% $Ca_{10}(OH)_2(PO_4)_6$ 40% $NaAlSi_2O_6H_2O$ 30% $4Na_2O \cdot CaO \cdot 4Al_2O_3 \cdot 2CO_2 \cdot 9SiO_2 \cdot 3H_2O$	Refinery
Ville Platte, Louisiana	30% $Ca_{10}(OH)_2(PO_4)_6$ 70% $NaAlSi_2O_6 \cdot H_2O$	Manufacturing
Brownsville, Texas	10% $Ca_{10}(OH)_2(PO_4)_6$ 60% $CaCO_3$ 20% $CaSO_4$ 10% $Ca_2Fe_2SiO_4(OH)_2$	Utility
Port Arthur, Texas	40% $Ca_{10}(OH)_2(PO_4)_6$ 40% Fe_3O_4 10% Fe_2O_3 10% $(MgFe)_3(SiAl)_4O_{10}(OH)_2 \cdot 4H_2O$	Refinery
Sweeney, Texas	50% $Ca_{10}(OH)_2(PO_4)_6$ 25% $CaSO_4$ 25% $5CaSiO_3 \cdot H_2O$	Refinery

TABLE II

Boiler Deposits Containing Silicon Compounds

Burt, New York	10% $Mg_3Si_2O_7 \cdot 2H_2O$ 90% $CaCO_3$	Food
Syracuse, New York	15% $Mg_3Si_2O_7 \cdot 2H_2O$ 15% $Mg(OH)_2$ 10% $CaSO_4$ 60% $CaCO_3$	Manufacturing
Springsboro, Pennsylvania	40% $Mg_3Si_2O_7 \cdot 2H_2O$ 10% $Mg(OH)_2$ 50% $CaCO_3$	Food
Cleveland, Ohio	50% $Mg_3Si_2O_7 \cdot 2H_2O$ 50% $CaCO_3$	Steamer
Columbus, Ohio	30% $Ca_3Fe_2(SiO_4)_3$ 10% $5CaSiO_3 \cdot H_2O$ 60% $CaCO_3$	Utility
Lowellville, Ohio	30% $4CaO \cdot Na_2O \cdot 6SiO_2 \cdot H_2O$ 70% $CaCO_3$	Steel
Middletown, Ohio	10% $Mg_3Si_2O_7 \cdot 2H_2O$ 10% $(MgFe)_3(SiAl)_4O_{10}(OH)_2 \cdot 4H_2O$ 10% Fe_2O_3 70% $CaCO_3$	Steel
Toledo, Ohio	25% $NaFe(SiO_3)_2$ 75% Fe_2O_3	Steamer
Toledo, Ohio	75% SiO_2 10% Fe_2O_3 10% NaCl 10% FeOOH, Alpha	Steamer
Youngstown, Ohio	15% $Mg_3Si_2O_7 \cdot 2H_2O$ 20% $Mg(OH)_2$ 40% $MgCO_3$ 25% $CaCO_3$	Steel
Detroit, Michigan	20% $Mg_3Si_2O_7 \cdot 2H_2O$ 15% $Mg(OH)_2$ 15% $CaCO_3$ 50% $CaSO_4$	Steamer
Monroe, Michigan	10% $Mg_3Si_2O_7 \cdot 2H_2O$ 90% $CaCO_3$	Paper
Muskegon, Michigan	10% $Mg_3Si_2O_7 \cdot 2H_2O$ 10% $CaCO_3$ 80% $CaSO_4$	
Green Bay, Wisconsin	50% $5CaSiO_3H_2O$ 50% $CaCO_3$	Metal
Madison, Wisconsin	20% $Mg_3Si_2O_7 \cdot 2H_2O$ 80% $CaCO_3$	Food
Aurora, Illinois	15% $Mg_3Si_2O_7 \cdot 2H_2O$ 35% $Mg(OH)_2$ 50% $CaCO_3$	Paper
Chicago, Illinois	30% $Mg_3Si_2O_7 \cdot 2H_2O$ 10% Fe_2O_3 60% $CaCO_3$	Railroad
Chicago, Illinois	25% $NaFe(SiO_3)_2$ 50% Fe_2O_3 25% Fe_3O_4	Utility
Chicago, Illinois	5% $Mg_3Si_2O_7 \cdot 2H_2O$ 85% $CaSO_4$ 5% $CaCO_3$ 5% Fe_3O_4	Utility
Rock Island, Illinois	15% $Mg_3Si_2O_7 \cdot 2H_2O$ 5% Fe_3O_4 15% $CaCO_3$ 50% $CaSO_4$ 15% $CaSO_4 \cdot \frac{1}{2}H_2O$	Metal
Baton Rouge, Louisiana	10% $Mg_3Si_2O_7 \cdot 2H_2O$ 10% $Mg(OH)_2$ 80% $CaSO_4$	Refinery
New Orleans, Louisiana	25% $Mg_3Si_2O_7 \cdot 2H_2O$ 70% $CaCO_3$ 5% SiO_2	Refinery
Atreio, Texas	60% $NaAlSi_2O_6 \cdot 2H_2O$ 10% SiO_2 Quartz 10% SiO_2 Cristobolite 20% Fe_2O_3	Refinery
Houston, Texas	40% $Mg_3Si_2O_7 \cdot 2H_2O$ 30% Fe_2O_3 30% Fe_3O_4	

TABLE III

Boiler Deposits Containing Copper

New York City, New York	5% Copper 10% Fe_2O_3 20% Fe_3O_4 10% $Mg_3Si_2O_7 \cdot 2H_2O$ 55% $Ca_{10}(OH)_2(PO_4)_6$	Utility
Atlantic City, New Jersey	10% Copper 10% Fe_2O_3 30% $NaAlSi_2O_6 \cdot H_2O$ 20% $(MgFe)_3(SiAl)_4O_{10}(OH)_2 \cdot 4H_2O$ 20% $Ca_{10}(OH)_2(PO_4)_6$	Utility
Perth Amboy, New Jersey	20% Copper 10% Fe_2O_3 30% $NaAlSi_2O_6 \cdot H_2O$ 20% $(MgFe)_3(SiAl)_4O_{10}(OH)_2 \cdot 4H_2O$ 20% $Ca_{10}(OH)_2(PO_4)_6$	Chemical
Beaver Falls, Pennsylvania	5% Copper 15% Fe_2O_3 5% $Mg_3Si_2O_7 \cdot 2H_2O$ 75% $Ca_{10}(OH)_2(PO_4)_6$	Building
Philadelphia, Pennsylvania	10% Copper 45% Fe_3O_4 15% Fe_2O_3 30% $Ca_{10}(OH)_2(PO_4)_6$	Utility
Akron, Ohio	5% Copper 10% Fe_2O_3 80% Fe_3O_4 5% SiO_2	Rubber
Toledo, Ohio	25% Copper 35% Fe_3O_4 25% $NaAlSi_2O_6 \cdot 2H_2O$ 15% $Ca_{10}(OH)_2(PO_4)_6$	Utility
Comstock, Michigan	10% Copper 70% Fe_2O_3 20% $Ca_3Fe_2(SiO_4)_3$	Utility
Flint, Michigan	10% Copper 10% Fe_2O_3 10% Fe_3O_4 70% $Ca_{10}(OH)_2(PO_4)_6$	Automotive
Milwaukee, Wisconsin	5% Copper 25% Fe_3O_4 75% $4CaO \cdot Na_2O \cdot 6SiO_2 \cdot 2H_2O$	Textile
Chicago, Illinois	15% Copper 30% Fe_2O_3 40% Fe_3O_4 15% $4Na_2O \cdot CaO \cdot 4Al_2O_3 \cdot 2CO_2 \cdot 9SiO_2 \cdot 3H_2O$	Utility

Chicago, Illinois	20% Copper 5% Fe_2O_3 50% Fe_3O_4 10% $Mg_3Si_2O_7 \cdot 2H_2O$ 15% $Ca_{10}(OH)_2(PO_4)_6$	Utility
Chicago, Illinois	15% Copper 30% Fe_2O_3 40% Fe_3O_4 15% $4Na_2O \cdot CaO \cdot 4Al_2O_3 \cdot 2CO_2 \cdot 9SiO_2 \cdot 3H_2O$	Utility
Freeport, Illinois	5% Copper 40% Fe_3O_4 40% $Mg_3Si_2O_7 \cdot 2H_2O$ 15% $Ca_{10}(OH)_2(PO_4)_6$	Manufacturing
Houston, Texas	10% Copper 10% Fe_3O_4 20% $Mg_3Si_2O_7 \cdot 2H_2O$ 60% $Ca_{10}(OH)_2(PO_4)_6$	Refinery

TABLE IV

Boiler Deposits Containing Sulfate

Olean, New York	70% $CaSO_4$ 30% $CaCO_3$	Manufacturing
Macedon, New York	10% $CaSO_4$ 60% $Mg(OH)_2$ 30% $CaCO_3$	Metal
Rochester, New York	80% $CaSO_4$ 5% Fe_2O_3 10% FeOOH, alpha 5% $CaCO_3$	Utility
Chester, Pennsylvania	80% $CaSO_4$ 10% $CaSO_4 \cdot 2H_2O$ 10% $Mg(OH)_2$	Metal
Bellevue, Ohio	30% $CaSO_4$ 45% Fe_3O_4 25% $CaCO_3$	Food
Cincinnati, Ohio	70% $CaSO_4$ 10% $Mg(OH)_2$ 20% $CaCO_3$	Railroad
Muskegon, Michigan	30% $CaSO_4$ 10% Fe_2O_3 10% $Mg(OH)_2$ 50% $CaCO_3$	Manufacturing
Madison, Wisconsin	45% $CaSO_4$ 50% $CaCO_3$ 5% Fe_3O_4	Food
St. Elmo, Illinois	10% $CaSO_4$ 90% $CaCO_3$	Refinery

TABLE V

Condenser Deposits

Buffalo, New York	50% FeOOH, alpha 40% FeOOH, gamma 10% Amorphous	Utility
Buffalo, New York	40% Fe_2O_3 40% Fe_3O_4 20% SiO_2	Steel
Rochester, New York	90% $CaCO_3$ 10% SiO_2	Utility
Bayonne, New Jersey	45% FeOOH, alpha 25% FeOOH, gamma 30% SiO_2	Refinery
Oil City, Pennsylvania	100% FeOOH, alpha	Refinery
Cleveland, Ohio	10% FeO 30% Fe_2O_3 30% Fe_3O_4 30% SiO_2	Steel
Columbus, Ohio	80% FeOOH, alpha 20% SiO_2	Utility
Columbus, Ohio	95% $CaCO_3$ 5% SiO_2	Utility
Youngstown, Ohio	100% $CaCO_3$	Steel
Whiting, Indiana	100% $CaMg(CO_3)_2$	Refinery
Whiting, Indiana	90% Fe_3O_4 10% $CaCO_3$	Refinery
Whiting, Indiana	20% Fe_3O_4 50% FeOOH, alpha 20% FeOOH, gamma 10% SiO_2	Refinery
Lansing, Michigan	100% $CaCO_3$	Utility
East St. Louis, Illinois	50% Fe_3O_4 40% $CaCO_3$ 5% $CaSO_4$ 5% SiO_2	Refinery
Pekin, Illinois	100% $CaMg(CO_3)_2$	Distillery
Wood River, Illinois	65% Fe_3O_4 35% $CaCO_3$	Refinery
Erath, Louisiana	100% $CaCO_3$	Refinery
Baytown, Texas	40% $CaCO_3$ 60% $Ca_{10}(OH)_2(PO_4)_6$	Refinery
Houston, Texas	95% $CaCO_3$ 5% SiO_2	Refinery
Houston, Texas	75% Fe_2O_3 10% $CaSO_4$ 5% SiO_2 10% Organic	Refinery
Houston, Texas	75% FeOOH, alpha 25% Fe_3O_4	Refinery
Texas City, Texas	100% $CaCO_3$	Refinery
Texas City, Texas	95% Fe_3O_4 5% SiO_2	Refinery

TABLE VI

Pipe Line Deposits

Corning, New York	20% Fe_2O_3 60% Fe_3O_4 20% FeOOH, alpha	Glass
Lackawanna, New York	20% Fe_2O_3 20% Fe_3O_4 50% SiO_2 15% $CaMg(CO_3)_2$	Steel
Olean, New York	25% Fe_3O_4 50% FeOOH, alpha 25% FeOOH, gamma	Refinery
Bayonne, New Jersey	15% Fe_3O_4 55% FeOOH, alpha 25% $Fe(OH)_3 \cdot Mg(OH)_2 \cdot 3H_2O$ 5% SiO_2	Refinery
Parlin, New Jersey	100% FeOOH, alpha	Chemical
Erie, Pennsylvania	100% $CaSO_4$	Paper
Alliance, Ohio	20% Fe_2O_3 60% FeOOH, alpha 20% FeOOH, gamma	Metal
Cleveland, Ohio	70% Fe_3O_4 10% FeOOH, alpha 20% $FeCO_3$	Metal
Middletown, Ohio	50% $CaCO_3$ 50% $Mg_3Si_2O_7 \cdot 2H_2O$	Steel
Ravenna, Ohio	35% $CaCO_3$ 15% $Mg_3Si_2O_7 \cdot 2H_2O$ 50% $Ca_{10}(OH)_2(PO_4)_6$	Chemical
Youngstown, Ohio	30% FeO 40% Fe_3O_4 20% FeOOH, alpha 10% $CaCO_3$	Electrical
Anderson, Indiana	50% $CaCO_3$ 20% $Mg_3Si_2O_7 \cdot 2H_2O$ 30% $Ca_{10}(OH)_2(PO_4)_6$	Electrical
Decatur, Indiana	20% Fe_2O_3 80% Fe_3O_4	Food
Fort Wayne, Indiana	15% Fe_2O_3 40% Fe_3O_4 20% FeOOH, alpha 25% $Ca_{10}(OH)_2(PO_4)_6$	Automotive
Lawrenceburg, Indiana	100% $CaCO_3$	Distillery
Lawrenceburg, Indiana	80% $CaCO_3$ 20% $CaSO_4$	Distillery
Whiting, Indiana	100% $CaCO_3$	Refinery
Bay City, Michigan	100% FeOOH, alpha	Coal Mine
Detroit, Michigan	30% Fe_2O_3 30% Fe_3O_4 40% FeOOH, alpha	Automotive
Flat Rock, Michigan	50% Fe_3O_4 15% FeOOH, alpha 10% $Na_8Al_6O_{24}(SO_4)_3$ 25% $Ca_{10}(OH)_2(PO_4)_6$	Municipal

Kalamazoo, Michigan	100% Fe_2O_3	Paper	Wood River, Illinois	60% Fe_3O_4 40% $Ca_{10}(OH)_2(PO_4)_6$	Refinery
Kaukana, Wisconsin	40% Fe_2O_3 60% Fe_3O_4	Paper	Wood River, Illinois	75% FeOOH, alpha 25% Fe_3O_4	Refinery
Rothschild, Wisconsin	20% Fe_2O_3 80% $Ca_{10}(OH)_2(PO_4)_6$	Paper	Baton Rouge, Louisiana	20% Fe_2O_3 40% FeOOH, alpha 20% FeOOH, gamma 20% SiO_2	Refinery
Chicago, Illinois	5% FeO 10% Fe_2O_3 40% Fe_3O_4 35% FeOOH, alpha 10% SiO_2	Utility	Baton Rouge, Louisiana	30% Fe_3O_4 10% FeOOH, alpha 60% $CaCO_3$	Refinery
Chicago, Illinois	30% FeOOH, alpha 10% FeOOH, gamma 60% $Fe_3(PO_4)_2 \cdot 8H_2O$	Municipal	Beauregard Parish, Louisiana	10% Fe_2O_3 50% Fe_3O_4 20% FeOOH, alpha 20% FeOOH, gamma	Railroad
Fairfield, Illinois	100% FeOOH, alpha	Municipal	Galveston, Texas	100% $CaCO_3$	Food
Lawrenceville, Illinois	50% $CaCO_3$ 50% Organic	Refinery	Freeport, Texas	100% $CaCO_3$	Chemical

TABLE VII

Distribution of Constituent Types in Deposits by States

STATE	Number of Deposits	Carbonates	Sulphates	Silicon Compounds	Phosphates	Hydroxide	Iron Oxides	Coppe
New York	16	8	5	9	5	1	10	1
New Jersey	7	0	0	6	4	1	7	2
Pennsylvania	10	3	2	5	6	3	6	2
Ohio	27	14	0	21	10	2	17	2
Indiana	12	8	1	5	5	1	4	0
Michigan	16	8	3	10	7	3	9	2
Wisconsin	8	5	1	4	3	0	6	1
Illinois	28	14	4	17	12	3	18	4
Louisiana	10	2	1	6	4	1	5	0
Texas	15	6	2	10	6	0	8	1
Total	149	68	19	93	62	15	90	15

TABLE VIII

Analysis of Drain Acid

SAMPLE	Weight in Lbs./Gal.	Inhibited Hydrochloric Acid Percent	DISSOLVED IRON			DISSOLVED CALCIUM			
			Percent Iron	Lbs. Iron/Gal.	Equivalent Lbs. Fe_3O_4 Gal.	Percent Calcium	Lbs. Calcium Gal.	Equivalent Lbs. $Ca_{10}(OH)_2(PO_4)_6$	Copper Percent
Top of Boiler	8.64	4.10	0.42	.0363	0.0502	0.09	.00778	0.0194	.0001
Center of Boiler	8.65	3.95	0.52	.0447	0.0618	0.10	.00865	0.0216	.0001
Bottom of Boiler	8.65	3.85	0.59	.0511	0.0706	0.11	.00952	0.0238	.0001
Average	8.65	3.96	0.51	.0440	0.0608	0.10	.00865	0.0216	....

Total gallons of solvent used—21,369.
Iron oxide (Fe_3O_4) scale dissolved— 0.0608 lbs. x 21,369 gals. =1300 lbs.
Hydroxy apatite scale ($CA_{10}(OH)_2(PO_4)_6$ — 0.0216 lbs. x 21.369 gals. — 462 lbs.
Total dissolved deposits — 1762 lbs.

TABLE IX

Operational Corrosion Data from Inhibited Acid Treatment of Boilers for East Coast Utilities

A. Boiler Treatment No.	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B. Date boiler was treated	11-6-43	7-28-44	4-14-45	11-13-43	6-27-44	4-20-45	2-26-44	3-10-45	3-2-44	8-2-45	7-25-45	8-15-45	3-23-45	3-30-45
C. Gallonage of acid	16260	16750	17000	13750	15800	17000	33000	32650	33000	9000	9000	9000	17500	17000
D. Percent HC1 in inhibited acid	5	4	4.5	5.5	4.5	4.9	3.7	4.0	4.5	6.3	6.3	5.4	4.5	4.35
E. Average Temperature, °F	160	170	175	170	170	175	175	165	170	130	135	125	170	170
F. Time in hours (filling, treating and draining)	7	7	7	7	7	7	10	6	12	12	12	8	7	9
G. Inside surface area exposed, sq. ft.	20000	20000	20000	20000	20000	20000	42750	42750	42750	12000	12000	12000	20000	20000
H. Percent Fe in drain acid	0.49	.....	0.35	0.45	0.31	0.40	0.56	0.30	0.56	0.83	0.61	0.64	1.21	0.33
I. Lbs. Fe in drain acid 8.3 x line C x line H	663	.....	497	515	408	567	1540	816	1540	621	458	480	1760	468
J. Lbs. Fe dissolved due to acid corrosion assumed in absence of ferric iron (assuming corrosion rate of 0.015 lbs./sq. ft./day)	87.5	87.5	87.5	87.5	87.5	87.5	206	122	248	67	67	45	76	95
K. Lbs. Fe due to iron oxide solubility and assumed ferric ion corrosion (line I minus J)	575	.....	409	427	320	479	1336	694	1292	554	391	435	1684	373
L. Lbs. Fe assumed to be due to ferric ion corrosion (29 percent of line K, based on 50 percent Fe_2O_3 and 50 percent Fe_3O_4)	167	.....	119	124	93	139	388	202	376	161	114	126	488	108
M. Lbs. Fe due to iron oxide solubility (line K—line L)	408	.....	290	303	227	340	948	492	916	393	277	309	1196	265
N. Lbs. iron oxide dissolved (line M x 1.43)	586	.....	415	434	325	486	1360	704	1312	562	396	442	1710	379
O. Cu. ft. of iron oxide dissolved (line N + (5.2 x 62.37))	1.81	.....	1.28	1.34	1.00	1.50	4.20	2.17	4.05	1.73	1.22	1.36	5.27	1.17
P. Thickness in inches of iron oxide on internal boiler surface before treatment (line O + line G x 12)	.0011	.....	.0008	.0008	.0006	.0009	.0012	.0006	.0011	.0017	.0012	.0014	.0031	.0007

DISCUSSION ON

"SELECTED BIBLIOGRAPHY ON SALT SPRAY TESTING, 1935-36," by Lorraine R. Voigt. Corrosion, 4, 492-500 (1948) Oct.

By L. M. FLAHERTY,
Bureau of Ships, Navy Department

It is noted that in the selected bibliography on salt spray testing which appeared on Page 492 of the October 1948 issue of CORROSION and of other articles which have also been included in CORROSION, that no mention has been noted of the use or requirement of the presence of ultra-violet light in salt spray testing. In the past, the Interior Communication and Fire Control Branch of the Bureau of Ships was given some concern by the corrosion of equipment which was installed in exposed locations on naval vessels. All of these equipments had been subjected to a constant salt spray test. These salt spray tests consisted of standard sea water and a constant spray on the test sample. It had been noted that these samples usually passed the salt spray requirements but began to corrode after a short period of operation at sea.

In an effort to equal conditions found at sea, an attempt was made to duplicate the conditions in a laboratory. As a result, a salt spray (fog) machine was designed to provide an accelerated test. Samples of materials were obtained from manufacturers. The samples were cut in half and the two sets of samples mounted on painted wooden plaques. One set of samples was mounted forward on the main deck of a ship and was exposed for six months and then returned to the bureau of examination. The other set of samples then was subjected to the salt spray test and after approximately 1000 hours, no corrosion was noted on the samples. In order to equal the elements found at sea, a source of ultra-violet light was added. After a period of 101 hours in the salt spray test, the two sets of samples had the same or equal amounts of corrosion. Based on these tests and findings, the salt spray requirements for equipment under this Branch are specified as follows:

> "When specified in the individual equipment specifications, a complete unit shall be subjected under ultra-violet light with a 20 percent hot salt spray at 130° F. for a period of three minutes, followed by a hot air blast at 130° F. for a period of three minutes. The cycle shall be repeated continuously for 100 hours. Upon completion of the test, the unit shall be disassembled, washed in fresh water, dried, examined and reassembled. Examination after the salt spray test shall show no appreciable corrosion or other damage to parts due to salt spray. In addition, all parts shall function satisfactorily after the material is reassembled. During tests, equipment shall be mounted in its normal installed position."

In connection with the above, it has been found that any equipment or finishes which will stand up under this test will also stand up under the conditions found at sea.

Any further details will be gladly furnished upon request by the Interior Communication and Fire Control Branch of the Bureau of Ships.

ERRATA

The following errors have been noted in the article, "Punched Cards for Filing Corrosion Test Results," by Lorraine R. Voigt, CORROSION, **4**, 582-589 (1948) Dec.

Page 585—Table 1, Line 11—"Acontic" Acid should be Aconitic Acid.

Page 587—Line 2—"(+1)" should be (2+1).
Line 3—"(+2)" should be (7+2).

Page 588—Table 4, Line 21—Bronze (85 Cu, "%" Sn, 5 Zn, 5 Pb) should be Bronze (85 Cu 5 Sn, 5 Zn, 5 Pb).
Table 4, Last Line—"Corrosion" should be Corros-iron.

Page 589—Beginning at bottom of column one, text should read: "The longest searches now take only 2 to 2½ hours instead of 28. In fact, specific data usually can be located so rapidly that an engineer can often . . ."

DISCUSSIONS ARE INVITED

Readers who wish to submit written information additive to articles published in CORROSION, or who wish to register differences of opinion with respect to any article are urged to send such discussions to Dr. Paul Bachman, Chairman, NACE Editorial Review Committee, Commercial Solvents Corp., Terre Haute, Indiana. Doctor Bachman will submit such discussions to a member of the review committee, and after review and approval the discussion will be published.

The expression of opinions about or the addition of information to that contained in technical articles will advance the interests of NACE and make CORROSION more valuable to the membership.

Organic Linings for Chemical Equipment*

By KENNETH TATOR

CORROSION control by means of organic linings and coverings has not attained the recognition in the corrosion literature which its long and successful use has earned for it. Rubber linings in commercial use long antedated the use of stainless steel, yet even in Uhlig's Corrosion Handbook[1] 106 pages have been devoted to stainless steels, only one of the many types of corrosion-resistant alloys, whereas some 58 pages cover all types of organic materials, and of these 58 pages considerable space is devoted to a discussion of wood and structural paints.

The reason for this can be laid to several causes: First, until recent years, rubber, pitch and wood remained the only successful corrosion-resistant materials in industrial use; second, manufacturers of organic corrosion-resistant linings and coatings persist in obscuring the nature of their products in trade names which defy their classification and analysis according to proper scientific procedures, and the third and most pertinent reason has to do with the evolution of corrosion engineering.

KENNETH TATOR

President, Industrial Lining Engineers, Inc., Coraopolis, Pa., a graduate of Reed College and M. I. T., formerly was with Dewey and Almy Chemical Company, in various capacities. Preceding and during the war he was active in various major capacities in effecting the use of substitutes and in conservation projects and as special assistant to the rubber director in connection with raw materials problems in the synthetic rubber program. He has been president of his own company since 1944.

Earlier corrosion engineers, practicing without benefit of such a distinguished title, were predominantly metallurgists because their products were those which were being destroyed by corrosion. The metallurgical approach filled literature and paid off in the development of stainless steels, high silicon alloys, copper and nickel-bearing alloys, and other metals with low dissolution rates.

Somewhat later electrochemists, with the encouragement of the Electrochemical Society, helped to identify forces of corrosion, and developed practical methods of neutralizing these forces. Sacrificial anodes, cathodic protection, and the bulging pages of Corrosion all attest to the value of their approach.

Within the past few years, through development of an impressive list of new corrosion-resistant synthetic rubbers and plastics, corrosion control by organic barriers has been given new impetus and importance.

The corrosion engineer of today and the future cannot afford to be only a metallurgist, or an electrochemist, or a plastics or rubber technician. He must be intimately acquainted with the principles and tools of all three of these sciences. He must not think that each approach is competitive with, or a substitute for, another approach. Each has its predominant potentialities and its limitations and all should be considered the stock-in-trade of the corrosion engineer, to be used singly or in combination according to the requirements of the problem.

Organic materials function in corrosion protection as a physical, inert barrier between the corrosive environment and the corrodable metal. Under many conditions they serve also as insulating barriers which prevent completion of galvanic circuits arising from couples of dissimilar metals or stray currents. In the latter instance in cooperation with cathodic protection they are used extensively in the protection of buried pipe and steel structures from soil corrosion.

Corrosion-resistant metals do corrode, but at a rate so slow their service life under corrosive conditions is more than the required life of the equipment or structure in which they are incorporated. Organic linings, however, if properly selected are completely inert to corrosive environment at time of selection. This difference makes it impossible to classify them according to the quantitative yardstick adopted for metals, namely "inches of penetration per year." It

*A paper presented at the NACE conference in St. Louis, Mo., April 5-8, 1948.

can be stated truly of organic materials that if they resist the corrosive environment for sixty days they will resist it forever. That such long life is not realized in practice is due to foreign destructive influences such as mechanical injury, oxidation, or embrittlement due to progressive polymerization.

Organic materials with which every corrosion engineer should be familiar include natural rubber and the synthetic rubber, especially Buna S, Buna N, chloroprene and ethylene polysulphide and the plastics with particular regard to the phenolics and furanes, the various vinyl copolymers, vinylidene chloride, polystyrene, polythylene, methacrylates, melamine, silicons, and asphalts and pitches.

Unfortunately these materials too often are known to the corrosion engineer only by non-informative trade names accompanied by elaborate performance claims. Until such "patent medicine" tactics are discontinued by the manufacturer, organic barriers will not attain the prestige and status they properly deserve. The writer was at one time consulted in regard to a hot water corrosion problem in which the investigators had previously, by their own admission, "tried everything" and all linings had failed. Recognition of the trade names quickly revealed they had tested but one material, a vinyl chlor-acetate copolymer compounded by six different manufacturers.

The corrosion engineer should be familiar with the potentialities and limitations of each chemical group of organic materials used in corrosion work and should insist that each manufacturer of a proprietary material identify his product according to these groupings so that intelligent selection may be made without wasteful duplication of effort. Corrosion-resistant metals are sold by trade name yet their composition is a matter of public record.

In order to judge intelligently whether organic materials offer promise of solution of any corrosion problem, and in order to select the material most probable of success, certain questions must be considered. Answers to these questions will allow the engineer not only to select the most promising material, but also to determine the best methods and points of application, and the most economical lining thickness. These questions are:

1. Is the problem primarily one of keeping the corrosive agent, a product, free from the metallic contamination caused by corrosion?
2. Is corrosion galvanic in nature; in other words, is the corrosive agent an electrolyte which contacts dissimilar metals?
3. What is the temperature range over which the process operates?
4. What would be the rate of corrosion if no remedial measures are taken?
5. To what extent is the equipment liable to abrasion, erosion, or mechanical impact?
6. What is the concentration and chemical nature of the corrosive agent?

In the production of certain iron-free grades of caustic soda and such acids as phosphoric, muriatic and tannic it is desirable that these corrosive products not be contaminated by metallic corrosion products. In such cases organic barriers almost invariably are indicated. Corrosion-resistant metals all have low but real solution rates, and cathodic protection methods cannot, from a practical standpoint, be so exactly balanced to insure no solution from either the anodic or cathodic surface.

Where corrosion has been determined to be galvanic in nature, organic linings are worth special consideration as these are basically electrical insulators. As has been demonstrated by Seagren[2] and others in such instances, it is more important to cover the cathodic metal surface than the anodic, or corroding, surface. Covering either or both surfaces theoretically will stop the galvanic corrosion. But in event of imperfect application of the lining or subsequent damage to it a small area of cathodic exposure will result in a relatively low corroding current density distributed over the surface of the uncoated anode metal surface. However, at a break in the lining over an anodic surface all of the electrical energy generated by the system will be concentrated at the break, resulting in rapid perforation of the metal. Such cases of galvanic corrosion often are accelerated by use of corrosion-resistant alloys, as these may increase the cathodic area and increase the current density upon the anodic surface. Cathodic protection is, of course, an obvious solution where the corrosive agent is not too strong, and even with such cathodic protection, organic barriers are desirable to take care of variations in current density due to non-conformity of anodes to the corroding surface.

The temperature at which the process operates determines whether organic materials may be considered at all, and whether their choice must be confined to the relatively small list of thermosetting synthetic rubbers, phenolics, or silicones. Organic materials are decomposed at temperatures in excess of 500° F. At temperatures between 180° F. and 450° F. only thermosetting materials may be considered, as the temperature-sensitive thermoplastics will be so weakened in film strength and adhesion that their use would be contraindicated.

The rate of corrosion of the base metal by the corrosive medium will determine what savings, if any, may be realized by reducing the thickness of the lining. A liquid applied film of approximately one to ten mils thickness inevitably will be deficient in protection over edges, corners and well spatter, and may develop shrinkage cracks in pits and crevices. Furthermore, films of such thicknesses are fractured easily by impact, abrasion or erosion, thus exposing the base metal to corrosion. For these reasons, contrary to the implications of advertisements for many corrosion-resistant plastic-base points, their use should be confined to areas of mild corrosion such as the protection of structures or equipment from corrosive atmospheres, or to prevent metal contamination in a mildly corrosive product.

Where abrasion, erosion, and the probability of accidental impact is probable a resilient material should be selected for application in sufficient thickness to absorb the shock or wear. One-eighth of an inch generally might be considered minimum while a maximum of one-quarter inch will suffice for most purposes.

Having thus determined whether an organic material is capable of providing solution to the problem,

whether it should be applied as a thick or thin lining, whether it may be thermoplastic or must be thermosetting, and where and how it must be applied, the engineer now, and only now, should select the lining material to be used. By consideration of specific data such as is outlined in Table I these organic classes which do not meet the specifications thus far can be eliminated. It now is necessary to select from the remaining classes that material which is most inert to the corrosive agent, using data outlined in Table II as a guide. If a choice of materials is available cost of material and application will determine the choice.

In the use of the accompanying tables it must be kept in mind that they are useful only as a guide in the selection of organic lining materials. The organic classes in successful corrosion use today are shown, identified as to their thermoplastic or thermosetting nature, thickness of application limitations, general chemical resistance and non-resistance, impact and abrasion resistance, and methods of application. It must be appreciated that neither this chart nor this paper can possibly embrace all detailed data required to make an intelligent selection for all corrosion problems. But supplementary details may be acquired by the engineer with not too arduous additional study. It is to be hoped that corrosion handbooks in the future will give data in detail and with complete listings of chemical resistances and non-resistances of all of the various organic plastic and rubber bases.

In the chemical industry annual cost for corrosion ravages and remedial measures is easily 20 per cent and often 100 per cent of original plant cost. If any company planned to double plant facilities every one to five years, it certainly would be considered negligent if it did not maintain a staff of top-notch consulting and resident industrial architects and engineers to plan and supervise the expansions. Yet many, or rather most, chemical companies authorize annual expenditures of these magnitudes for repair or replacement of equipment and structures and protective maintenance with the responsibility for reducing or eliminating this expenditure given, if to anyone at all, as a part time duty to some chemist, maintenance superintendent, master painter, or engineer who invariably is hard-pressed in fulfillment of his regular duties. Consequently this problem of corrosion, usually the largest single source of potential cost reduction in the whole plant, receives but superficial attention.

It is high time that company officers recognize the cost of corrosion in their operations and realize that something can be done about it if done intelligently by properly qualified corrosion engineers. Building a plant entirely of stainless steel, or flooding it with a magic plastic paint, or bathing it in a beam of anions will not prevent corrosion but may even accelerate it. Corrosion can be materially reduced only by an-

TABLE NO. I—GENERAL PROPERTIES

MATERIAL	Generic Name	Thermal Characteristics	Thickness Available	Methods of Application	Field Repairability
Rubbers:					
Butadiene-acrylo-nitrite	Buna N	Thermo-setting	5 mils to ½″	Latex, solution, sheet	Compromise repairs only
Butadiene-styrene	Buna S	Thermo-setting	5 mils to ½″	Latex, solution, sheet	Compromise repairs only
Chloroprene	Neoprene*	Thermo-setting	5 mils to ½″	Latex, solution, sheet	Compromise repairs only
Ethylene poly-sulphide	Thiokol*	Thermo-setting	5 mils to ½″	Latex, solution, sheet	Compromise repairs only
Natural rubber	.....	Thermo-setting	5 mils to ½″	Latex, solution, sheet	Compromise repairs only
Plastics:					
Melamine	.....	Thermo-setting	⅛ to ½″	Sheet	Compromise repairs only
Methacrylates	.....	Thermo-plastic	⅛ to ½″	Sheet	Repairs of reasonable quality
Phenol-formaldelyde	Phenolic	Thermo-setting	1 to 6 mils	Solution	Compromise repairs only
Phenol-furfural	Furane	Thermo-setting	1 to 6 mils	Solution	Compromise repairs only
Polyethylene	.....	Thermo-plastic	⅛ to 3/32″	Hot melt	Good quality—readily made
Polystyrene	.....	Thermo-plastic	1 mil to ½″	Solution, hot melt, sheet	Good quality—readily made
Silicones	.....	Thermo-setting	1 mil to ½″	Solution, paste, sheet	Repairs of reasonable quality
Vinyl aceto-chloride	Vinyl	Thermo-setting	1 mil to ½″	Solution, latex, sheet, paste	Repairs of reasonable quality
Vinylidene chloride	Saran*	Thermo-setting	1 mil to ½″	Latex, sheet	Repairs of reasonable quality

* Trade name given where coating is sold under only one trade name.

TABLE NO. II—RESISTANCES

MATERIAL	Temperature Range	Inorganic Acids	Organic Acids	Alkalis	Oxidizing Agents	Oils	Organic Solvents	Impact and Abrasion
Rubbers:								
Butadiene-acrylonitrite	—20 to 230° F.	G	G	G	P	E	G	E
Butadiene-styrene	—20 to 190° F.	E	G	E	P	P	G	E
Chloroprene	—20 to 230° F.	E	G	E	G	E	G	E
Ethylene-polysulphide	—20 to 120° F.	*	*	*	P	E	G	P
Natural rubber	—20 to 190° F.	E	G	E	P	P	P	E
Plastics:								
Melamine	—20 to 200° F.	G	G	G	P	G	*	P
Methacrylates	—20 to 180° F.	E	G	E	E	G	*	P
Phenol-formaldehyde	—20 to 375° F.	E	E	P	P	E	E	P
Phenol-furfural	—20 to 375° F.	E	E	G	P	E	E	P
Polyethylene	—20 to 180° F.	E	E	E	E	P	G	P
Polystyrene	—20 to 170° F.	E	G	E	E	P	G	P
Silicones	—20 to 500° F.	G	G	G	*	G	*	P
Vinyl acetochloride	—20 to 180° F.	E	G	E	E	E	*	G
Vinylidene chloride	—20 to 200° F.	E	G	E	E	E	*	G

E—Inert (Excellent).
G—Inert in general, but with some important exceptions (Good).
*—Resistance varies with specific corrosion medium.
P—Poor.

alyzing each corrosion area section by section, drawing up remedial specifications for each section, structure and piece of equipment, and supervising the installation and maintenance of these corrective measures.

By this sort of intelligent, planned corrosion control it will be found that the most economical and effective corrective systems will be combinations of corrosion-resistant metals, plastics, rubbers, corrosion inhibitors, and/or cathodic devices, these combinations varying from area to area depending upon the specific corrosion environment and operating conditions.

Furthermore, scientific corrosion control must be considered on the equipment designer's and plant architect's drawing tables. At this stage many modifications and adjustments may be made economically which may save thousands of dollars in the efficiency and life of the corrosion-proofing subsequently installed. For chemical equipment the simple design precaution of specifying ⅛-inch to ¼-inch radius on all exposed edges and outside corners and fillet welding all inside corners and recesses will prolong the life of organic linings from two to twentyfold.

This type of corrosion-control program can be realized only by corrosion engineers, retained or resident, who have no other responsibilities, and earn and are given the cooperation of all departments of the company. Needless to say these corrosion engineers must be metallurgists, electrochemists, or rubber and plastics technologists and must use the products of all these sciences.

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Mitigation of Corrosion on City Gas Distribution Systems*

By A. D. SIMPSON, JR.*

I. Introduction

The purpose of this paper is to relate in a general way the magnitude of corrosion leakage experience on United Gas Corporation city distribution systems and experience with cathodic protection in the mitigation of corrosion.

It is not the intention of the writer to delve into the theory of cathodic protection. However, an attempt will be made to relate from the gas distribution system operator's point of view the need for cathodic protection on steel gas distribution mains, the method employed in application of cathodic protection to mains and the results obtained. The practical operator, although interested in the theory of cathodic protection, is more concerned with what it will do and how much it will cost.

For historical background, while this article contains much material originally presented by C. L. Morgan at the American Gas Association Meeting in 1945, it also includes performance data and experience gained since that time.

Need For Corrosion Mitigation

IN 1930, UNITED Gas acquired a number of gas distribution systems in the Gulf section of Texas and Louisiana. Steel mains in these systems are of sizes from 2 to 20 inches and most were installed between 1925 and 1930. Practically all steel mains were treated with a protective covering consisting of a pipe line paint primer and one application of hot asphalt. The pipe then was wrapped with felt and rolled in sawdust. Although some care was given to the application of the coating to lengths of pipe in treating yards or over the trench and during backfill, the pipe usually received rough treatment before it reached the bottom of the trench. Welds, fittings, and service connections were not always coated. No attempt was made to prevent galvanic corrosion caused by action of dissimilar metals, and the mains were not insulated from other metallic structures.

These systems when acquired, therefore, consisted of steel mains poorly coated as compared with present-day standards, having numerous bare spots and fittings and metallic connections with other underground structures in the immediate vicinity. These gas systems were connected to the local water system by accidental contacts between the two structures and by connections through gas water heaters.

Soil in which these systems are located is corrosive. Shortly after the systems were acquired, failures in the mains began to occur. These failures became more frequent with increased age.

Failures in the mains continued to develop, resulting in numerous gas leaks, and it was necessary for some of the mains to be repaired, reconditioned, or replaced. This work was expensive, especially in sections under concrete pavement. The value of gas lost, in most instances, was very small in comparison with the cost of making repairs; however, the operating condition created by the existence of leaks required that the leaks be eliminated as promptly as possible after detection, regardless of the cost. This repair work was annoying to the public, especially in congested areas requiring night work.

In 1941, corrosion leaks were occurring so frequently on steel welded mains in the business section of Houston that serious consideration was given to replacing the mains. These mains consist principally of 6-inch and 10-inch steel pipe, totaling 24,000 feet exclusive of service lines. Estimate of replacement cost was set at $102,500. There were 24 corrosion leaks detected and repaired on the mains during 1941. The cost of finding and repairing these 24 leaks was $2500. The curve, Figure 1, indicates the leaks that were found and repaired on these lines since 1931.

When the accumulated leakage curve is projected at the same trend as indicated between 1935 and 1943, the accumulated leaks on this downtown Houston area would have exceeded 1500 in the next 10 years. From a standpoint of dollars and cents value, it would cost more to operate the system for the next ten years than it would cost to completely replace it. It was believed that if new leaks could be prevented, the estimated saving in operating expense would be

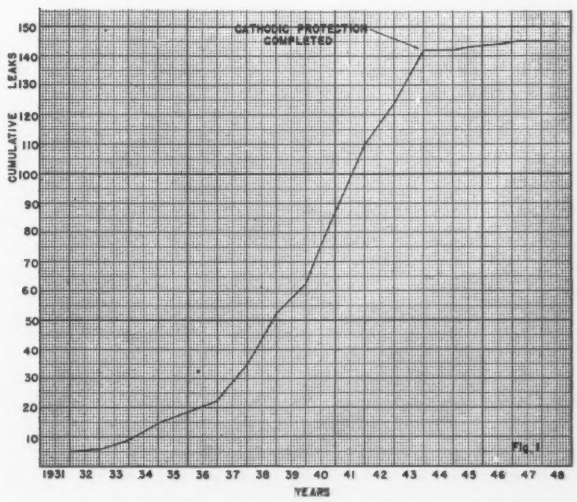

Figure 1—Cumulative corrosion leaks on the steel mains in the business section of Houston.

★ A Paper Presented at South Central Regional Meeting, NACE, Tulsa, Okla., September 21, 1948.

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in the order of 70 percent of the total yearly expenditure on this section.

Corrosion Mitigation Investigation and Early Experimental Installations

Rectifier

In 1938, a rather feeble attempt was made to arrest corrosion on several isolated sections of one of the larger distribution systems with cathodic protection by the use of small rectifier units, but the results were far from satisfactory, mainly because of the incompleteness of installations and lack of proper attention to their operation.

In late 1941, a rectifier installation was made at Westlake, Louisiana. This unit was used to protect 12,000 feet of 6-inch main running through a river swamp in a very corrosive area. This main, a high pressure feeder for Lake Charles, had no service connections. The only insulation necessary to separate the main from the system was insulating four 6-inch valve flanges.

This was done satisfactorily, and the results were complete protection on approximately 9000 feet of the 12,000 feet of main. Several leaks have been found and repaired on the section of main that was not completely protected, but the over-all results have been a decrease from 13 leaks in 4 years to 2 leaks in 7 years.

In view of the difficulty of installing rectifiers in congested locations, experiments were started in Houston to determine the possibility of protecting mains and services in this area with galvanic anodes.

Galvanic Anodes

Experiments were conducted in Houston to determine current requirements for cathodic protection of mains. The experiments indicated that mains with coatings comparable to coatings on those in the business section and located in similar soils responded readily to cathodic protection. It was found that current requirements for protection were surprisingly low if the mains were insulated from all other metallic structures. Results of the experiments were so encouraging that in the fall of 1942, it was decided to attempt to protect welded steel mains in the business section of Houston and in other "hot spots" in the system by cathodic protection, using zinc anodes as a current source.

The decision to use zinc as a source of current was reached after considerable experiment, investigation and deliberation. It was believed zinc anodes properly placed and distributed could be used satisfactorily to protect coated mains, and by using zinc, the concentration of excessive current at any one location could be avoided.

Although zinc had been used as a current source for protecting a few long transmission lines, there was very little information available on the performance of zinc over a period of years. The meager information available indicated that although in some locations the zinc remained active for years, in other locations it became passive in a year or two and failed to deliver appreciable current to the lines. It seems that the environment or type of soil in which the zinc was located was an important factor in the performance of the zinc. The purity of the zinc is believed to be especially important in preventing local action on the anode.

In the absence of sufficient information regarding the performance of zinc in different environments and under different conditions over a long period, a number of short period tests were conducted to obtain information on the performance of zinc in Houston. The results of these tests were used as a guide in the first installations. A larger number of tests were set up to be run over a period of several years to obtain more detailed and conclusive data on performance of zinc over longer periods.

The results of the earlier experiments with rectifier and short period tests with zinc convinced us that cathodic protection was definitely worth trying on a large scale basis.

In 1943, we placed 30 miles of 3-inch equivalent steel gas mains in Houston under cathodic protection.

Results From Early Cathodic Protection Installations

From the cathodic protection installations made, we found that preparation of mains to receive protection was probably the most expensive part of the installation.

Insulating of Mains

Included in the preparation of mains to receive cathodic protection was insulating it from accidental contacts with foreign pipe lines, underground cables, etc., and from the remainder of the distribution system. In most cases the separation was done by insulating flanges of existing valves with the line in service. It was found that the gasket material between valve flange and companion flange usually provided satisfactory insulation between the flanges. Bolts were insulated from flanges by removing them one at a time and enclosing them in non-metallic tubes and using non-metallic washers under steel washers. This method of insulation was very satisfactory and inexpensive. In a few cases, it was necessary to install special insulating fittings in the mains.

Frequently it was desirable to operate several sections together, and in those cases bonds were installed across insulated fittings. Service connections usually were insulated at the meter, thereby providing protection for the service line. Intentional contacts, consisting principally of bond wires to other structures originally installed during existence of the electric street railway system as a cooperative drainage program, were found and cleared. Accidental contacts were the most troublesome, as there was no record of their existence.

Current Requirements

It was found that after mains were cleared from all contacts and electrically insulated from the distribution system average current requirements to change the potential between the mains and remote $CuSO_4$ electrode contacting the earth from —0.60 volt to —0.85 volt was 0.21 milliampere per square foot of pipe surface.

This value of current in the terms of zinc anodes

would mean that one zinc anode, ½" x 3" x 36", weighing 14 pounds and costing approximately $2.15 ready to install, would protect 69 feet of 6-inch main for over 20 years.

Actual cost of this yearly cathodic protection program is difficult to ascertain. The work of applying cathodic protection was often done at the same time and by the same crews doing other work. It was, therefore, necessary to divide the expense between several different jobs, and it is difficult to do this accurately. It is also a problem to determine how much of the research and investigation expense and how much of the expense of designing and assembling instruments and equipment should be included with the cost of each installation. An attempt has been made to determine a reasonably accurate cost of doing the work. This cost is obviously most important because even though the results are satisfactory, the cost might be prohibitive. After careful analysis of all the expense involved in the installation of protection, it was found that the average cost of protecting a mile of 6-inch main in the business section of Houston was approximately $2000. This cost included all expense incurred from the first preliminary survey until installations were completed and in operation.

Maintenance of Original Installations

Maintenance of cathodic protection has been inexpensive. Average cost per mile of 3-inch equivalent was approximately $11 per year for this original installation. One principal factor that has influenced this cost has been that men maintaining these mains also have been continuing the cathodic protection program. This has made it possible to charge only the actual time and material used to the pipes protected. Otherwise, with a very small amount of pipe under protection, considerable standby and stores expense would have been incurred.

Leakage Reduction

Protection to all mains in the business section was completed in the early part of 1944. No corrosion leaks occurred on any of these lines during the year 1944, one leak had been found through July, 1945, and two leaks since, although an average of 19 corrosion leaks each year was found and repaired in the years 1941, 1942 and 1943. The cumulative leak record of mains now protected in the downtown section of Houston is shown on Figure 1. Although complete protection to these lines may have been obtained, an occasional leak may develop because there probably are a number of deeply corroded places on the mains that may result in leaks as the pipe is vibrated by street traffic, disturbed by soil stress, or strained when internal gas pressures in the mains are increased. From an operating point of view, it is readily apparent that the life of these mains has been extended indefinitely and our original estimate of a saving of 70 percent of yearly operating and maintenance expenditure has been realized. Based on the results obtained, new mains placed under cathodic protection would be subject to no loss of mechanical strength and may be operated at maximum pressures indefinitely.

System-Wide Activity—1944-1948

Protected Pipe Footage

In view of the remarkable results obtained in the downtown Houston area in 1943, it was decided to continue our activities in cathodic protection work. We have applied cathodic protection to 204 miles of 3-inch equivalent since January, 1944. The breakdown of all pipe by sizes under complete cathodic protection as of June 30, 1948, is as follows:

Total Mains and Services Protected

¾"	20,539'
1"	75,566'
1¼"	42,502'
2"	414,125'
3"	10,973'
Total under 4"—64 miles 3" equivalent.	
4"	155,683'
5"	16,752'
6"	150,259'
8"	64,723'
10"	12,592'
12"	31,450'
14"	5,647'
16"	4,174'
Total 4" and over—175 miles 3" equivalent.	
Total pipe	1,004,985'

Total 3" equivalent—239 miles.

This does not include an estimated 75,000 feet of 1-inch service lines connected to protected mains by standard Dresser couplings. A large percentage of these services is receiving protection through iron bound Dresser couplings.

To protect this pipe, we have installed approximately 19 tons of zinc, 8 tons of magnesium, and reconditioned three existing rectifiers.

Source of Current

Galvanic anodes are used almost exclusively as a source of protective current. As a general rule, galvanic anodes are preferred in congested locations as they are adapted readily for this type of installation. Total current can be controlled readily by the number of anodes installed and the spacing between anodes.

Galvanic Anodes

By using zinc or magnesium, United Gas has been able to install galvanic anodes satisfactorily at practically all locations at which it was desirable to provide cathodic protection. When using galvanic anodes, the physical and electrical characteristics of the anodes must be considered if a reasonable amount of current output and life of anode is to be expected. The material used and the arrangement of individual anodes are determined by the desired current output, soil resistivity, space available, and to some extent the chemical composition of the soil. These factors are determined by a complete investigation of the pipe line to be protected and the soils in the vicinity of the pipe line. The anode installations are made, whenever possible, in soils that have low resistivity and remain moist.

The anode installations are made in accordance

with standard procedure set up by the General Office Engineering Department.

Zinc Anodes

Zinc frequently is used on the system as a source of protective current. Its primary advantage is believed to be stable operating characteristics and high operating efficiencies. These two factors make it satisfactory for protecting well coated lines in average soil. Its chief disadvantage is low driving voltage. United Gas has installed approximately 38,000 pounds of zinc anodes on its system. This zinc is giving complete cathodic protection to 159 miles of 3-inch equivalent mains and services.

United Gas has standardized on one size zinc anode. The 14-pound ½" x 3" x 36" rolled zinc plate has proved reasonably flexible in application and of sufficient bulk to permit design of ground bed installation for satisfactory life expectancy. Anodes used are better than 99.9 percent pure zinc. Principal impurities are in the order of: 0.08 percent lead, 0.0 percent iron, 0.004 percent cadmium.

So far, tests have revealed no undue local action or abnormal performance of a zinc anode due to impurities in the zinc. Normally New Jersey Zinc Company's Mix No. 1 or equivalent is specified.

Figure 2 illustrates the method used in preparing the anodes for installation. Figure 3 illustrates standard zinc installation for use in average soil conditions. This is assumed to be soil of approximately 1000 ohm centimeter.

To increase the size of installation, it is necessary only to increase the number of drilled holes and zinc anodes. This may be done in a straight line configuration, or if local conditions prevent this, the zinc may be located on both sides of the pipe line. When the available space is limited, spacing between holes is reduced to 10 feet, but this usually results in a decrease in current output per anode due to mutual interference. If soil condition permits, the hole may be drilled deeper and more plates placed in each hole.

In soils of approximately 1000 ohm centimeter such as those in the vicinity of Houston, a current output of 20 milliamperes per plate or better at a pipe to soil voltage of 0.90 volts negative can be expected. This gives an expected life of 20-25 years which is considered satisfactory. When installing zinc in soil

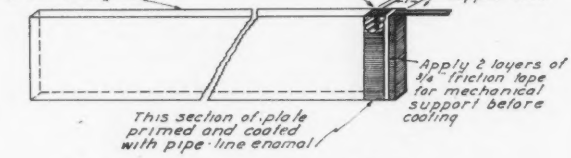
Tin end of wire and solder in 3/16" hole - 1" deep
"Zinc anode - 14# 1/2" thick - 3" wide - 36" long or 23# - 5" long
4' of #12 RC copper wire
Apply 2 layers of 3/4" friction tape for mechanical support before coating
This section of plate primed and coated with pipe line enamel

Figure 2—Method of attaching pigtail to zinc anode.

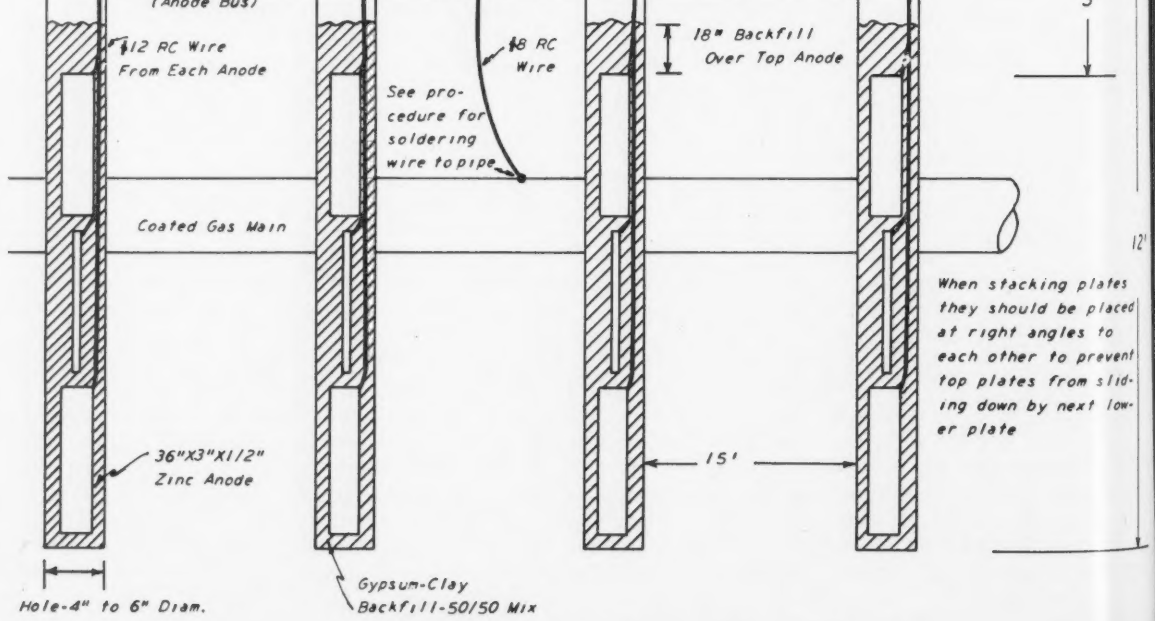
Leads long enough to extend 1' above curb box. Solder connection or use brass or bronze split bolt connector. Covered with heavy grease.
Curb Box
#10 RC Wire (Anode Bus)
Natural Soil
3'
#12 RC Wire From Each Anode
#8 RC Wire
18" Backfill Over Top Anode
See procedure for soldering wire to pipe
Coated Gas Main
12'
When stacking plates they should be placed at right angles to each other to prevent top plates from sliding down by next lower plate
36"X3"X1/2" Zinc Anode
15'
Gypsum-Clay Backfill-50/50 Mix
Hole-4" to 6" Diam.

Figure 3—Example of 12-plate zinc anode installation connected to coated gas main.

below 1000 ohm centimeter, zinc stacks usually are placed closer together to limit current output in order to maintain desired life expectancy.

In higher resistance soils from 1500 to 2500 ohm centimeter, zinc is installed as indicated on Figure 4. While this type of installation results in about 5 per-cent more current per anode than that realized from the closer spaced anodes previously mentioned, it is believed the extra current is worth the additional work. Two plates per hole sometimes are used when high resistance soil substrata makes it desirable to keep the zinc as close to the surface as practical.

Figures 5 and 6 illustrate the use of "distributed" zinc anodes to protect an uninsulated section of bare pipe line. When a section of pipe can be insulated from the line, it usually is found to be more economical to install the galvanic anodes in groups at intervals of 300 to 500 feet.

Zinc vs. Magnesium Anodes

United Gas does not believe it good practice to install zinc anodes in soil of higher resistivity than 2500 ohms per cubic centimeter whenever it is possible to avoid doing do. If it is necessary to install galvanic anodes in high resistance soil, magnesium or magnesium alloy is preferred.

Since the end of the war, United Gas has started using magnesium and magnesium alloy anodes to protect pipe with poor coating and pipe in high resistance soils. The higher driving voltage of magnesium as compared to zinc makes it more satisfactory when a relatively large amount of current is necessary and space for the anode installation is limited.

When protecting old pipe, it usually is found to be more economical to use magnesium as a source of current. For this type of installation, the anode installation usually is designed for approximately 10-year life expectancy.

In the case of new pipe or well-coated pipe, zinc is used most often because of the relatively small current requirement and long life desired from the anode installation.

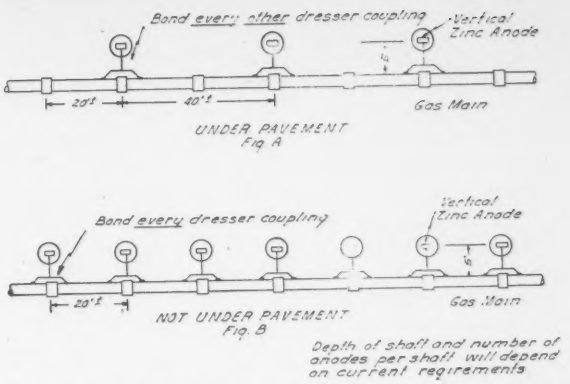

Figure 5—Use of distributed zinc anodes to protect Dresser coupled bare pipe line.

Magnesium or Magnesium Alloy Anodes

Magnesium or magnesium alloy anodes are procured in three general types, as indicated on Figure 7. Type 1 is approximately 4 inches D shape or square and 60 inches long; the average weight is 58 pounds. Type 2 is approximately 4 inches in diameter and 20 inches long, and the average weight is 18 pounds. Type 3 is approximately 8 inches in diameter

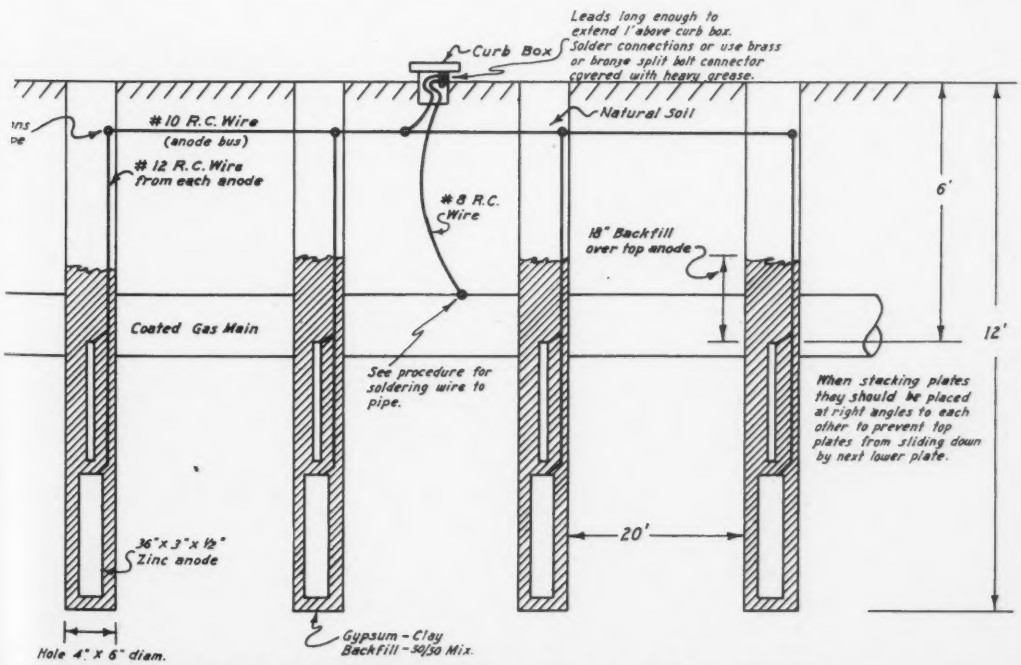
Leads long enough to extend 1' above curb box.
Curb Box
Solder connections or use brass or bronze split bolt connector covered with heavy grease.
#10 R.C. Wire (anode bus)
#12 R.C. Wire from each anode
Natural Soil
#8 R.C. Wire
18" Backfill over top anode
6'
Coated Gas Main
See procedure for soldering wire to pipe.
12'
When stacking plates they should be placed at right angles to each other to prevent top plates from sliding down by next lower plate.
20'
36"x 3"x 1/2" Zinc anode
Hole 4" x 6" diam.
Gypsum - Clay Backfill - 50/50 Mix.

Figure 4—Example of 8-plate zinc anode installation connected to coated gas main.

by 16 inches long and weighs approximately 52 pounds.

Of the three types, No. 3 has less general application. No. 2 is used interchangeably with No. 1 in general application.

Magnesium alloy anodes used are approximately: 90 percent magnesium, 0.1 percent copper, 3 percent zinc, less than 0.015 percent iron, 6 percent aluminum, 0.2 percent manganese, trace of nickel and silicon.

This alloy usually is sold under the trade name "Dowmetal." Solution potential is slightly less than cell magnesium, but it has proved satisfactory for use as a galvanic anode.

Standard magnesium installation is illustrated on Figure 8. This installation is used in soils ranging from 500 to about 1500 ohm centimeter. Normal current output is about 250 milliamperes per anode in 1000 ohm centimeter soil with pipe-to-soil voltage of 0.90 negative to remote copper sulphate reference electrode. The life expectancy of this type installation is 10 to 12 years.

Figure 9 illustrates the same general type of installation except that three 4 inch diameter x 20 inch anodes, weighing 18 pounds, are used. This type of installation is used under the same conditions as that under which the single large anodes are used.

In relatively high resistance soils, the center short anode is omitted, giving an installation as indicated

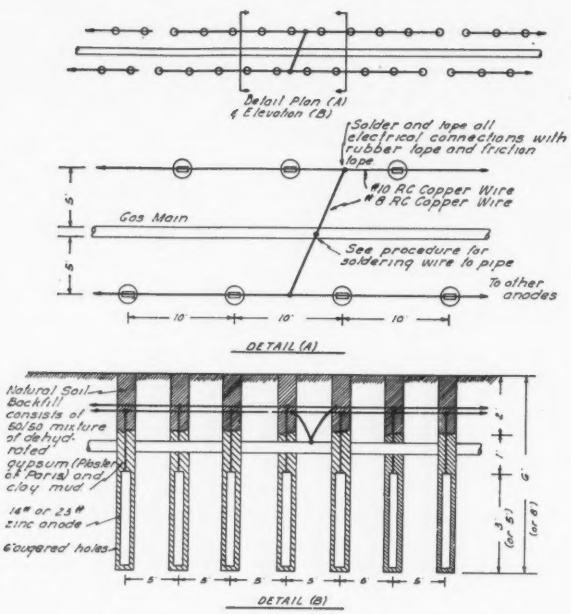
Detail Plan (A) & Elevation (B)
Solder and tape all electrical connections with rubber tape and friction tape
#10 RC Copper Wire
#8 RC Copper Wire
Gas Main
See procedure for soldering wire to pipe
To other anodes
10'
DETAIL (A)
Natural Soil
Backfill consists of 50/50 mixture of dehydrated gypsum (Plaster of Paris) and clay mud
14# or 23# zinc anode
6" augered holes
DETAIL (B)

Figure 6—Use of distributed zinc anodes to protect uninsulated sections of bare pipe.

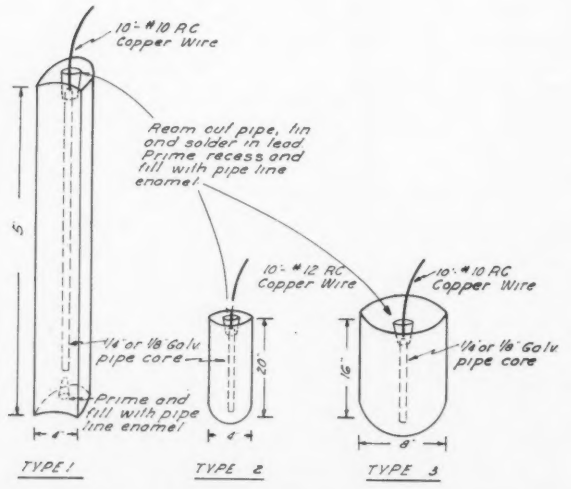
10'-#10 RC Copper Wire
Ream out pipe, tin and solder in lead. Prime recess and fill with pipe line enamel
10'-#12 RC Copper Wire
10'-#10 RC Copper Wire
1/4" or 1/8" Galv pipe core
Prime and fill with pipe line enamel
TYPE 1
TYPE 2
TYPE 3

Figure 7—Types of magnesium anodes.

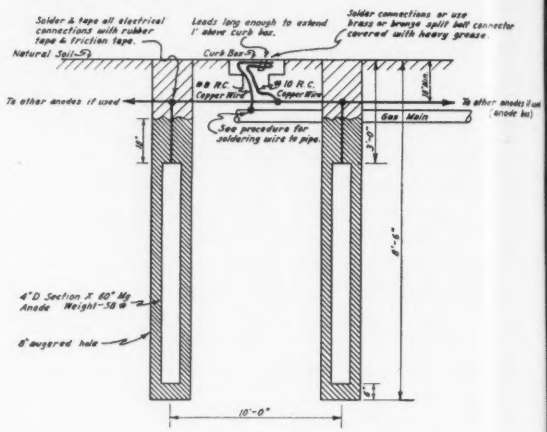
Solder & tape all electrical connections with rubber tape & friction tape.
Leads long enough to extend 1' above curb box.
Solder connections or use brass or bronze split bolt connector covered with heavy grease.
Natural Soil
Curb Box
#8 R.C. Copper Wire
#10 R.C. Copper Wire
To other anodes if used
Gas Main
See procedure for soldering wire to pipe
4"D Section X 60" Mg Anode Weight-58 #
8" augered hole
10'-0"

Figure 8—Vertical type of magnesium installation using anodes five feet long.

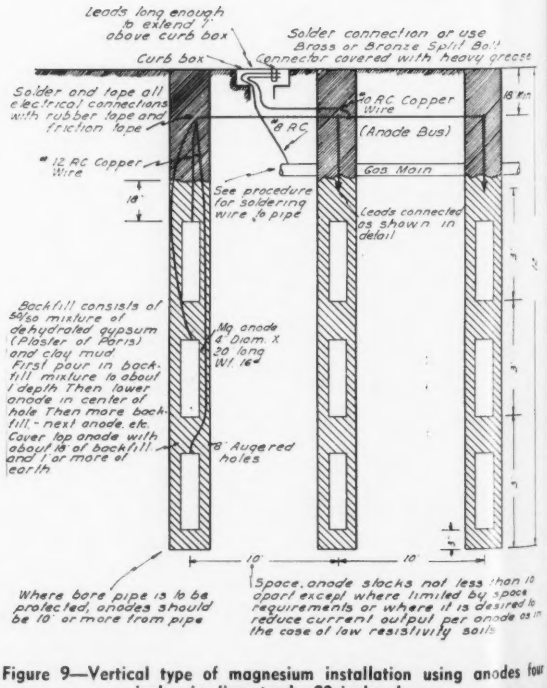
Leads long enough to extend above curb box
Curb box
Solder connection or use Brass or Bronze Split Bolt Connector covered with heavy grease
Solder and tape all electrical connections with rubber tape and friction tape
#10 RC Copper Wire
#8 R.C. (Anode Bus)
#12 RC Copper Wire
Gas Main
See procedure for soldering wire to pipe
Leads connected as shown in detail
Backfill consists of 50/50 mixture of dehydrated gypsum (Plaster of Paris) and clay mud. First pour in backfill mixture to about 1 depth. Then lower anode in center of hole. Then more backfill - next anode, etc. Cover top anode with about 18 of backfill and 1 or more of earth.
Mg anode 4" Diam. X 20 long Wt. 16#
18" Augered holes
Where bare pipe is to be protected, anodes should be 10' or more from pipe
Space anode stacks not less than 10 apart except where limited by space requirements or where it is desired to reduce current output per anode as in the case of low resistivity soils

Figure 9—Vertical type of magnesium installation using anodes four inches in diameter by 20 inches long.

on Figure 10. As in the case of zinc in high resistance soils, the magnesium anodes are spaced wider apart to limit the mutual interference to a minimum.

Sometimes it is necessary to install galvanic anodes in very low resistance soils (200 ohm centimeter or lower), such as salt-impregnated soils. In an installation of this type, it is necessary to use anodes of large bulk and small area. So far, the most satisfactory anode that United Gas has found for this type of installation is the 8 inch x 14 inch magnesium anode. By placing the anodes relatively close together, it is possible to limit the current output sufficiently to give a reasonable life expectancy. An example of this type installation is illustrated in Figue 11.

United Gas has at present approximately 61 miles of 3 inch equivalent mains and services protected by magnesium or magnesium alloy. Sixteen thousand pounds of magnesium have been installed to protect this pipe.

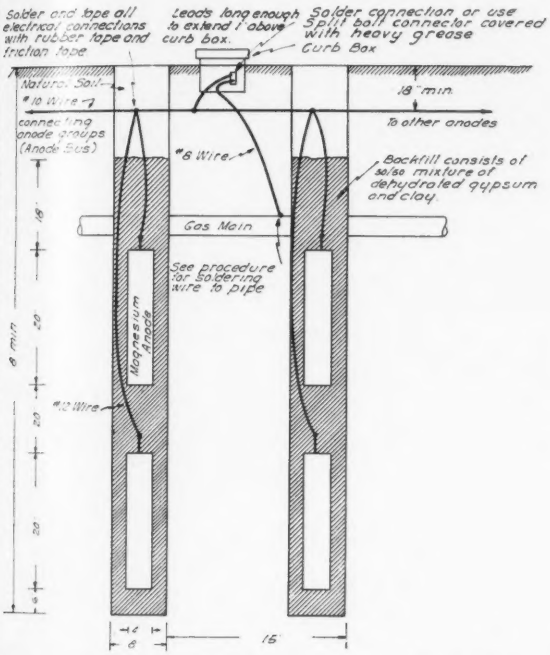
Solder and tape all electrical connections with rubber tape and friction tape
Leads long enough to extend 1' above curb box.
Solder connection or use Split bolt connector covered with heavy grease
Curb Box
Natural Soil
#10 Wire
connecting anode groups (Anode Bus)
18" min.
To other anodes
#8 Wire
Backfill consists of so/so mixture of dehydrated gypsum and clay
Gas Main
See procedure for soldering wire to pipe
Magnesium Anode
#10 Wire
8 min.
4
8
16

Figure 10—Magnesium installation using anodes four inches in diameter by 20 inches.

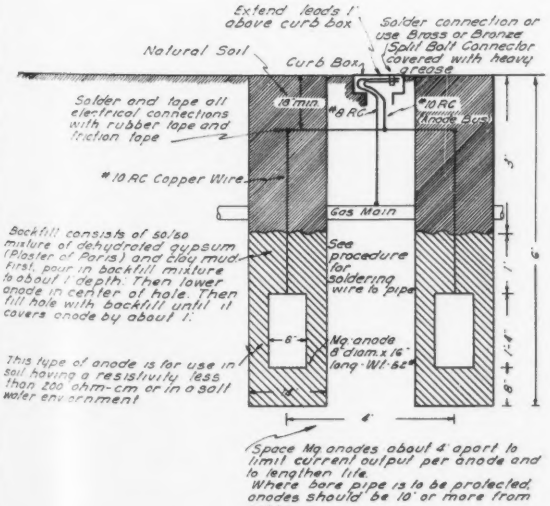
Extend leads 1' above curb box
Solder connection or use Brass or Bronze Split Bolt Connector covered with heavy grease
Natural Soil
Curb Box
Solder and tape all electrical connections with rubber tape and friction tape
18" min.
#8 RC
#10 RC (Anode Bus)
#10 RC Copper Wire
Gas Main
Backfill consists of so/so mixture of dehydrated gypsum (Plaster of Paris) and clay mud. First, pour in backfill mixture to about 1' depth. Then lower anode in center of hole. Then fill hole with backfill until it covers anode by about 1'.
See procedure for soldering wire to pipe
6'
Mg. anode 8" diam. x 16" long. Wt. 62
This type of anode is for use in soil having a resistivity less than 200 ohm-cm or in a salt water environment
Space Mg anodes about 4' apart to limit current output per anode and to lengthen life. Where bare pipe is to be protected, anodes should be 10' or more from pipe.

Figure 11—Vertical type of magnesium installation using anodes eight by 16 inches.

Anode Backfill

Better performance can be expected from galvanic anodes when they are installed in a suitable backfill. Material normally used for backfill for both zinc and magnesium consists of 50 percent dehydrated gypsum (Plaster of Paris) and 50 percent ground drilling clay. This material often is purchased ready-mixed from a local oil field supplier. It sometimes is used dry, but the preferred method is to mix the backfill with enough water to make a slurry and pour the mixture into the anode hole. Advantage of the wet mix is that the anode goes to work immediately at practically full output.

The usual method of mixing the backfill with water is to use a 6-volt electric mixer and pour the mixture into the anode hole before it starts to set up. The mixture never gets hard, but it does have a tendency to set up to a thick paste.

Rectifiers

At present, United Gas has approximately 19.5 miles of 3 inch equivalent mains and services protected by rectifiers. These rectifiers are operating very satisfactorily and have paid for themselves many times over in leak prevention. Rectifiers are located in isolated sections, and at all except one electric power was available at the location previous to installation of the rectifier. This permits use of small rectifiers without paying a premium in power in the form of a minimum monthly payment.

Rectifier ground beds are made up of scrap pipe. In one instance, an abandoned cast iron main was used. Junk steel pipe is used at the other installations.

Problems Encountered When Applying Cathodic Protection

Insulating Underground Contacts

Cathodic protection is applied to two classes of pipe. First and more expensive is old pipe in service. When applying protection, it is necessary to insulate this pipe from the rest of the system and all foreign lines, usually without interrupting service. To do this successfully, it is necessary to use insulated fittings at all points of interconnection with unprotected mains, insulate all service meters, and separate all accidental contacts with metallic structures. In general, the accidental contacts with water pipes or unprotected gas piping are the most expensive to clear. The actual work of clearing the contact once it is located may be small, but due to the highly congested areas in which we operate, it is sometimes rather difficult to locate the contact.

The majority of underground contacts are located from the ground surface by means of a pipe locator set. While the actual operation of a pipe locator for

by 16 inches long and weighs approximately 52 pounds.

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This alloy usually is sold under the trade name "Dowmetal." Solution potential is slightly less than cell magnesium, but it has proved satisfactory for use as a galvanic anode.

Standard magnesium installation is illustrated on Figure 8. This installation is used in soils ranging from 500 to about 1500 ohm centimeter. Normal current output is about 250 milliamperes per anode in 1000 ohm centimeter soil with pipe-to-soil voltage of 0.90 negative to remote copper sulphate reference electrode. The life expectancy of this type installation is 10 to 12 years.

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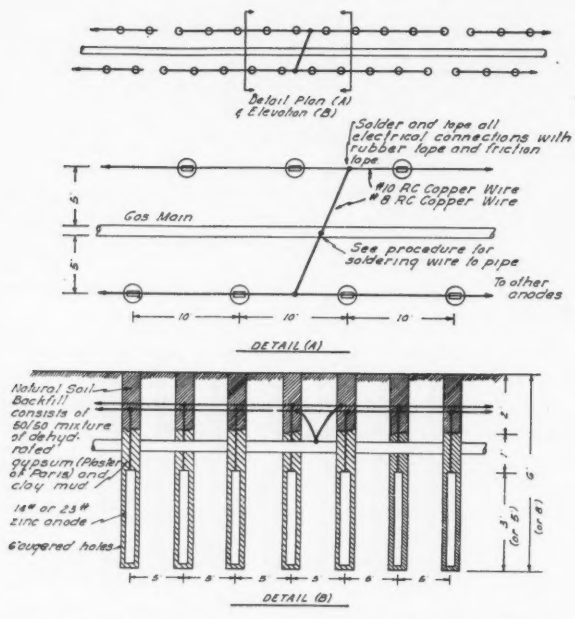

Figure 6—Use of distributed zinc anodes to protect uninsulated sections of bare pipe.

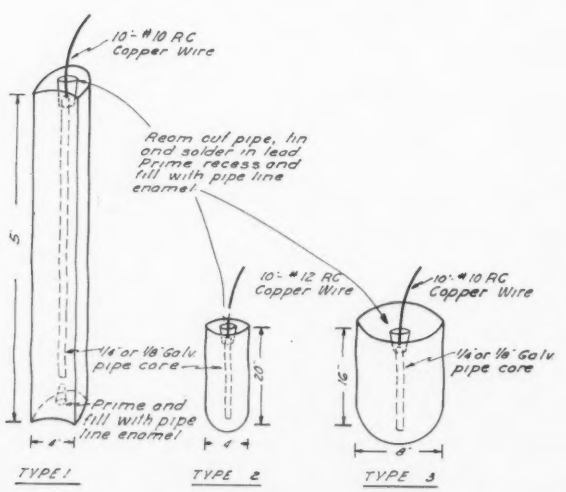

Figure 7—Types of magnesium anodes.

Solder & tape all electrical connections with rubber tape & friction tape.
Leads long enough to extend 1' above curb box.
Solder connections or use brass or bronze split bolt connector covered with heavy grease.
Natural Soil
Curb Box
#8 RC Copper Wire
#8 10 R.C. Copper Wire
To other anodes if used
To other anodes if used (anode bus)
Gas Main
See procedure for soldering wire to pipe
3'-0"
8'-6"
4" D. Section X 60" Mg Anode Weight-38 #
6" augered hole
10'-0"

Figure 8—Vertical type of magnesium installation using anodes five feet long.

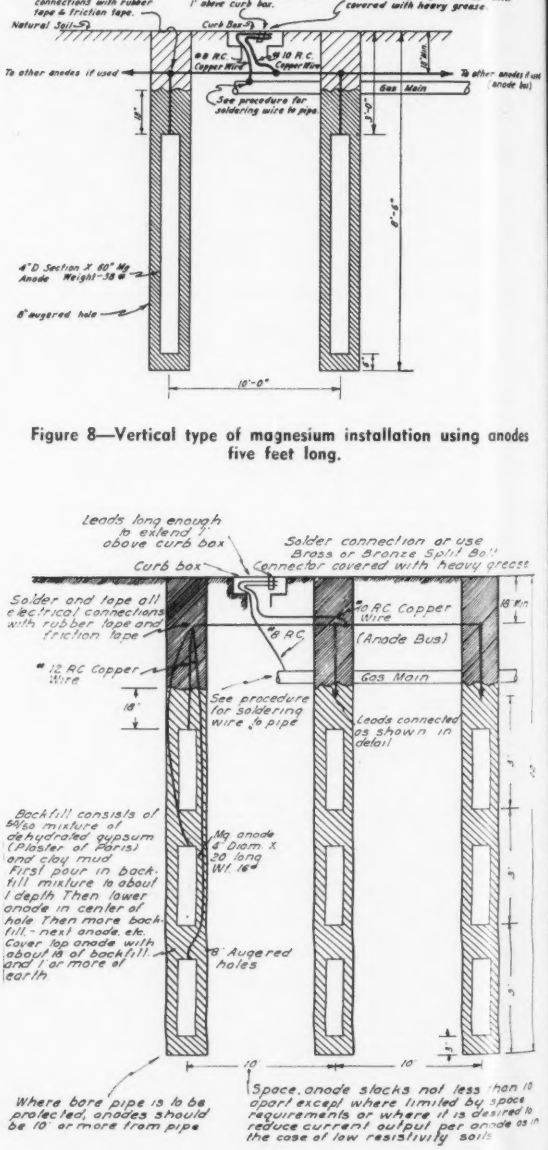
Leads long enough to extend 1' above curb box
Solder connection or use Brass or Bronze Split Bolt Connector covered with heavy grease
Curb box
Solder and tape all electrical connections with rubber tape and friction tape
#10 RC Copper Wire
#8 RC
(Anode Bus)
#12 RC Copper Wire
Gas Main
18" Min
18"
See procedure for soldering wire to pipe
Leads connected as shown in detail
Backfill consists of 50/50 mixture of dehydrated gypsum (Plaster of Paris) and clay mud First pour in backfill mixture to about 1 depth Then lower anode in center of hole Then more backfill - next anode, etc. Cover top anode with about 18 of backfill and 1 or more of earth
Mg anode 4" Diam. X 20 long Wt. 16#
18" Augered holes
10
10
Where bare pipe is to be protected, anodes should be 10' or more from pipe
Space anode stacks not less than 10 apart except where limited by space requirements or where it is desired to reduce current output per anode as in the case of low resistivity soils

Figure 9—Vertical type of magnesium installation using anodes four inches in diameter by 20 inches long.

on Figure 10. As in the case of zinc in high resistance soils, the magnesium anodes are spaced wider apart to limit the mutual interference to a minimum.

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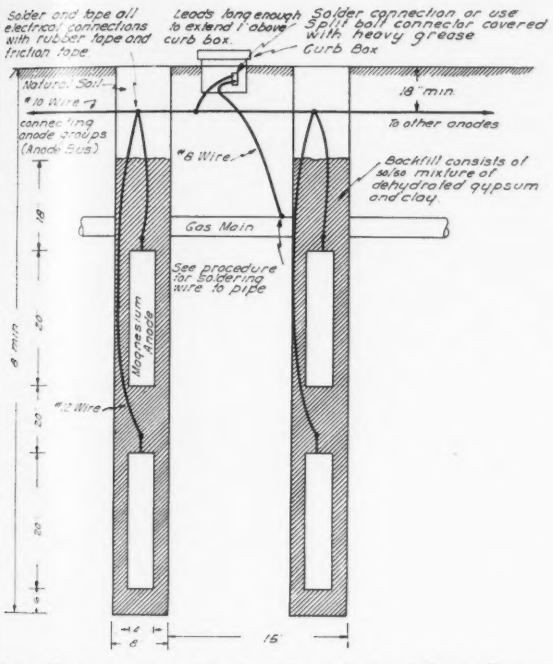

Figure 10—Magnesium installation using anodes four inches in diameter by 20 inches.

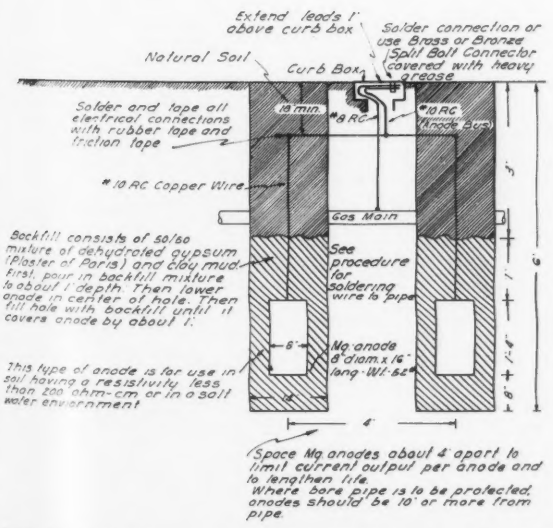
Extend leads 1' above curb box
Solder connection or use Brass or Bronze Split Bolt Connector covered with heavy grease
Natural Soil
Curb Box
Solder and tape all electrical connections with rubber tape and friction tape
18" min.
#8 RC
#10 RC Anode (Set)
#10 RC Copper Wire
Gas Main
Backfill consists of 50/50 mixture of dehydrated gypsum (Plaster of Paris) and clay mud. First pour in backfill mixture to about 1' depth. Then lower anode in center of hole. Then fill hole with backfill until it covers anode by about 1'.
See procedure for soldering wire to pipe
Mg anode 8" diam. x 16" long-Wt. 52#
This type of anode is for use in soil having a resistivity less than 200 ohm-cm. or in a salt water environment
6'
6'
4'
Space Mg anodes about 4' apart to limit current output per anode and to lengthen life. Where bare pipe is to be protected, anodes should be 10' or more from pipe.

Figure 11—Vertical type of magnesium installation using anodes eight by 16 inches.

Anode Backfill

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Rectifier ground beds are made up of scrap pipe. In one instance, an abandoned cast iron main was used. Junk steel pipe is used at the other installations.

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Insulating Underground Contacts

Cathodic protection is applied to two classes of pipe. First and more expensive is old pipe in service. When applying protection, it is necessary to insulate this pipe from the rest of the system and all foreign lines, usually without interrupting service. To do this successfully, it is necessary to use insulated fittings at all points of interconnection with unprotected mains, insulate all service meters, and separate all accidental contacts with metallic structures. In general, the accidental contacts with water pipes or unprotected gas piping are the most expensive to clear. The actual work of clearing the contact once it is located may be small, but due to the highly congested areas in which we operate, it is sometimes rather difficult to locate the contact.

The majority of underground contacts are located from the ground surface by means of a pipe locator set. While the actual operation of a pipe locator for

this specialized application may depend to some extent on the operator's past experience when locating contacts in congested locations, United Gas has found it to be satisfactory and reliable. Figures 12, 13, 14, 15, and 16 illustrate the use of the pipe locator for this application. Purpose of these drawings is to illustrate to operating personnel actual mechanics of operation without going into the theory. Methods illustrated may be used to check and recheck a suspected contact.

Insulating Meters

Since the majority of United Gas service lines are connected to the water system through water heaters, it has been found necessary to insulate every service at the meter installation. Small meters usually are insulated by the use of an insulating bushing, coupling, nipple or meter swivel. The type of insulating fitting used is determined by local condition and fitting previously used in the area. To date, United Gas has not found an insulating fitting considered entirely satisfactory when considered in relation to installation costs, possible breakage and other considerations.

Large meters usually are insulated by means of one or more insulating flange assemblies.

Insulating Pipe Line Fittings

When insulating existing flanges in service, it is the policy to insulate only the bolts and depend on the gasket material between the flanges to provide insulation. This has worked out very successfully in above-ground installations but has given some trouble when used underground. This is believed to be due to the presence of moisture in the asbestos gasket material. When possible, insulated flanges are assembled with a full size insulating gasket between the flange faces.

Preferred method of insulating underground is by using an insulating-type Dresser coupling. This fitting is subject to failure due to burrs on pipe or misalignment of ends of pipe cutting the rubber gasket. However, if reasonable care is taken when installing, little or no trouble is to be expected from its use.

Many old mains are Dresser coupled at one or many locations. When these couplings are indicated accurately on maps, they may be uncovered and bonded readily, but in many cases the couplings were

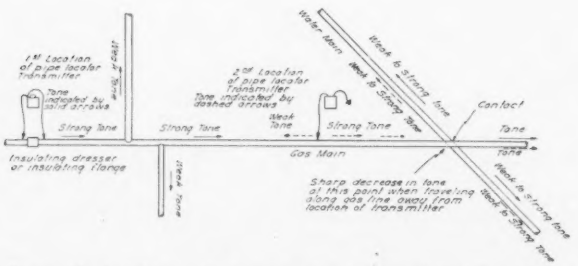

Figure 12—Locating contact using pipe locator. Note: Pipe locator transmitter may be connected between gas pipe and water or gas pipe and anode lead.

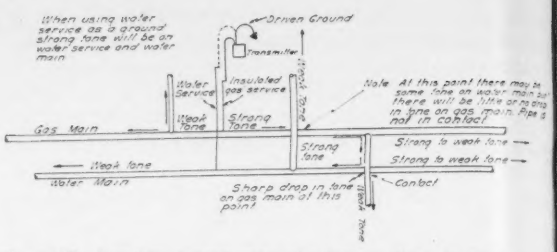
When using water service as a ground strong tone will be on water service and water main
Driven Ground
Transmitter
Water Service
Insulated gas service
Weak Tone
Strong Tone
Note At this point there may be some tone on water main but there will be little or no tone on gas main. Pipe is not in contact
Gas Main
Strong Tone
Strong to weak tone
Strong to weak tone
Weak tone
Water Main
Sharp drop in tone on gas main at this point
Contact
Tone

Figure 13—Locating contact using pipe locator. Note: If driven ground used, little or no tone is to be expected on water main unless contact exists. When the water main is used for ground connection there will be a strong tone on the water main even if no contact exists.

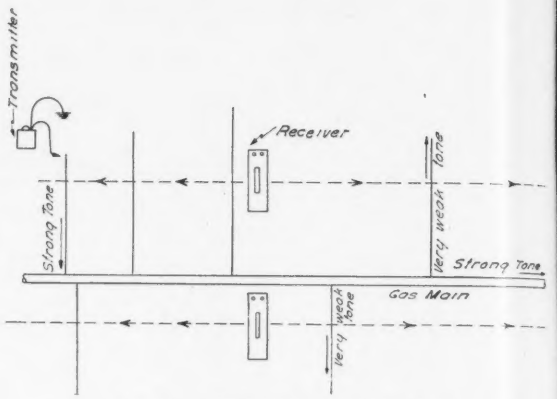

Figure 14—Method of testing service lines.

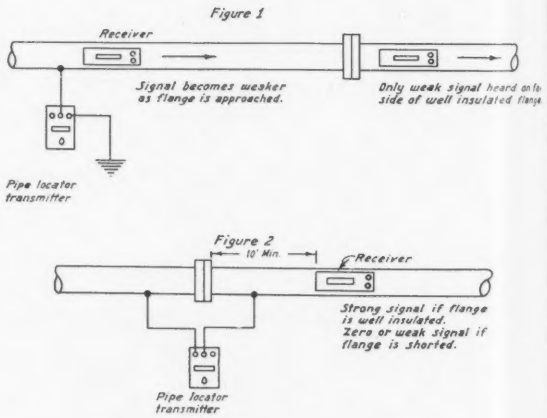
Figure 1
Receiver
Signal becomes weaker as flange is approached.
Only weak signal heard on far side of well insulated flange
Pipe locator transmitter
Figure 2
10' Min.
Receiver
Strong signal if flange is well insulated. Zero or weak signal if flange is shorted.
Pipe locator transmitter

Figure 15—Checking insulating flanges.

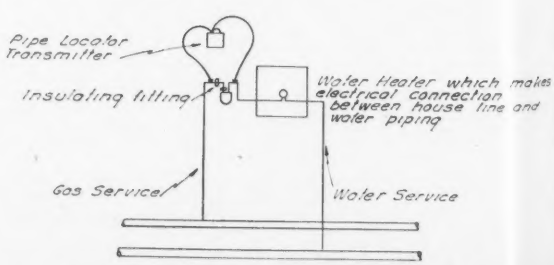
Pipe Locator Transmitter
Insulating fitting
Water Heater which makes electrical connection between house line and water piping
Gas Service
Water Service

Figure 16—Method of checking meter insulating fitting.

installed at the convenience of the construction forces and not entered on construction notes. Unless the coupling is completely iron bound, it is necessary to locate the coupling and install suitable bonds before complete protection of piping can be obtained. Small pipe usually is bonded by soldering or brazing a No. 8 or larger copper wire directly to the pipe and coupling. Figure 17 illustrates methods commonly used by United Gas to locate open or practically open Dresser couplings.

Revised Construction Standards

Realizing that cathodic protection on mains and services would be more general in the future, United Gas standards for new construction have been revised so that cathodic protection may be applied. All Dresser couplings except insulating couplings are electrically bonded at installation.

All meters and other tie-ins are insulated at installation if cathodic protection is anticipated. Contacts with foreign pipe lines and other metallic structures are avoided. These changes in construction practices not only reduce the cost of cathodic protection but serve to prevent galvanic corrosion caused by connecting dissimilar metals.

United Gas has found that if the protected system is divided into small sections, considerable savings will be realized in locating accidental contacts or other troubles that may appear. A typical example is illustrated in Figure 18, showing an installation

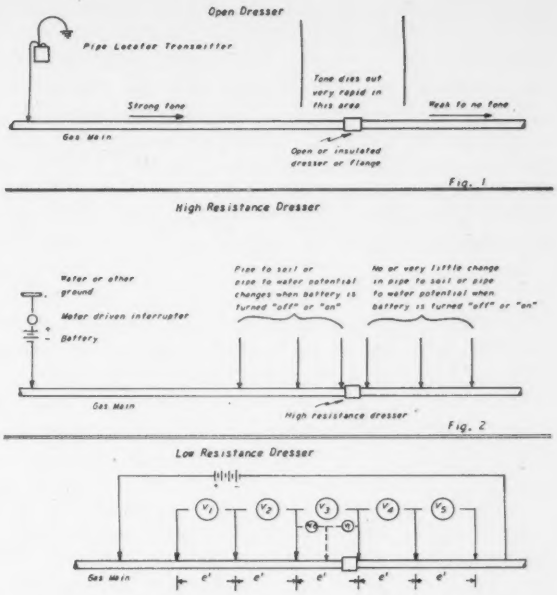
Open Dresser
Pipe Locator Transmitter
Tone dies out very rapid in this area
Strong tone
Weak to no tone
Gas Main
Open or insulated dresser or flange
Fig. 1
High Resistance Dresser
Water or other ground
Water driven interrupter
Battery
Pipe to soil or pipe to water potential changes when battery is turned "off" or "on"
No or very little change in pipe to soil or pipe to water potential when battery is turned "off" or "on"
Gas Main
High resistance dresser
Fig. 2
Low Resistance Dresser
Gas Main

Figure 17—Methods of locating open Dresser coupling. Low resistance Dresser: Test points equally spaced. $V_1 = V_2 = V_4 = V_6$, V_3 will be greater than other voltage drops V_1, V_2, V_4 or V_5. V_1 greater than V_2. The voltage drop measured across the section in which the Dresser is located will be greater than voltage drop across any section of equal length.

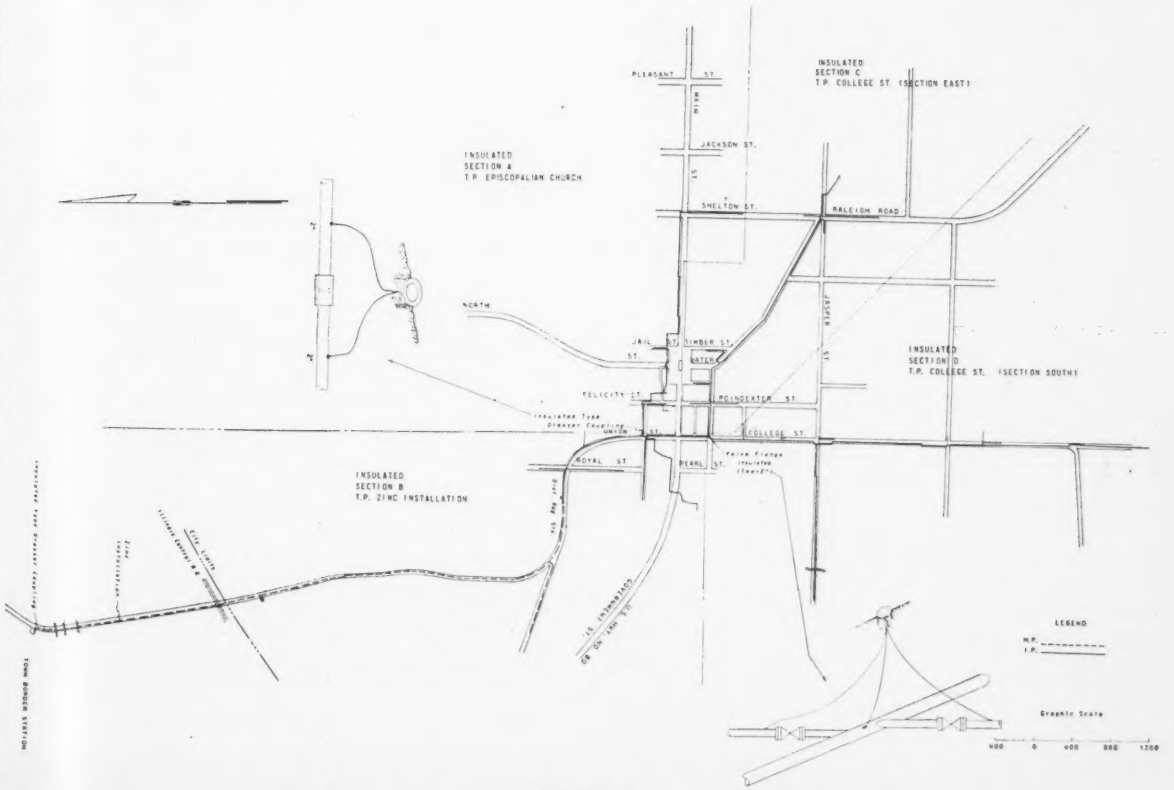

Figure 18.

in Mississippi. It will be noted this system is divided electrically into four approximately equal sections.

This system is protected by a zinc installation on the high-pressure main right-of-way. Test points are arranged so that accidental opening at one test circuit will not cause loss of protection on the entire system.

In actual operation of this system, two accidental contacts were located within thirty minutes by utilizing the sectionalization test points. Considering the fact this system has over seven miles of pipe, actual time spent locating the contacts was less than that for a man to walk the system.

Co-ordination With Other Utilities

Every precaution possible is being taken to prevent interference with other utilities operating underground. This has been carried to the extent of notifying interested utilities when and what lines are being placed under protection and making tests for their information if requested. This activity is considerably handicapped by a lack of joint co-ordinating committees among many utilities operating underground. It is believed that as cathodic protection becomes more general, co-ordinating committees will be set up and greater emphasis placed on the co-ordination of this activity.

Cathodic Protection Maintenance

Insulation

A chief concern has been the maintenance of complete cathodic protection. At time of installation, all known contacts are cleared, meters insulated, and any other insulating or bonding work that might be indicated is done, but it would be impractical to uncover the pipe line to bond every iron-bound Dresser coupling and re-insulate every pipe line or cable crossing. Even if this were done, it would not prevent the water company, telephone company, electric company or one of the many oil companies from laying a new line or moving an old pipe, resulting in a contact between our protected pipe and a relatively large unprotected structure. In addition to all foreign hazards, construction and maintenance forces will continue to run new pipe, set meters, and perform other activities, any one of which could result in an uninsulated meter connection or other contact between protected pipes and unprotected pipes.

When all possibilities are considered, it looks like a hopeless situation, but in actual practice it has not only proved practical to maintain cathodic protection but very economical to do so even with relatively untrained personnel.

Cathodic Protection Operation Data

Two methods are used to obtain the necessary operating data to insure proper operation of cathodic protection installations. These methods differ primarily according to the type of installation to which applied. In Houston where extensive cathodic protection installations are in use and a crew is working at cathodic protection full time, it is possible and practical to make routine pipe-to-soil potential readings at selected locations throughout the system. These readings are made periodically and recorded. A graphic record of one location is indicated on Figure 19. As can be noted readily, any trend is quickly indicated by comparing the present with previous tests. In the event loss of complete protection is indicated, steps are taken to eliminate the trouble and restore protection.

The second situation is the relatively small installation in small distribution systems. At these locations it is necessary for local personnel to make routine tests and inspections necessary to maintain protection.

Normally, these men do not have and are not trained to use instruments necessary to measure pipe-to-soil potentials. In cases of this type, a permanent indicating voltmeter is installed. This meter is installed and connected between protected pipe and unprotected pipe at a frequently visited location, such as a district regulator house or meter house. Arrangements are made for reading the voltmeter at periodic intervals and making a permanent record of the reading. When any marked variation from previous readings is noted, arrangements are made to have corrosion engineers visit the installations and make any adjustments necessary.

Maintenance Costs

It has been found possible to maintain complete cathodic protection for less than $10.00 per year per mile of 3 inch equivalent. This value includes labor, material and outside assistance that may be necessary from specially trained engineers.

Leakage Reduction

Over-all Cathodic Protection Results

Over-all results from United Gas cathodic protection program can be realized best by comparing leakage record for the last 12 months on protected pipe, to actual corrosion leakage on the same pipe the last years before protection was applied. In the year before cathodic protection, 79 corrosion leaks were detected and repaired. This is one leak per year per 1.4 miles of 3 inch equivalent of old mains and services.

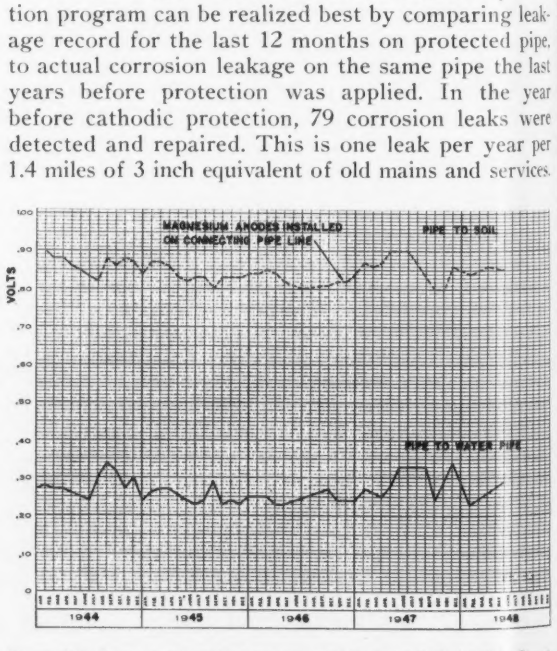

Figure 19—Pipe-to-soil and pipe-to-waterpipe potential. Market Street-Gainesville Street section. Monthly reading by cathodic protection maintenance personnel.

The same pipe after protection had 11 small leaks, or one leak per year per 10 miles of 3 inch equivalent.

As an outstanding example of results obtained, in one section of 24,000 feet of pipe (10.34 miles 3 inch equivalent), there were 24 corrosion leaks detected and repaired in one year previous to application of cathodic protection. Since placed under cathodic protection, three leaks have been detected and repaired in 4½ years. The comparative change has been a reduction in leaks from 2.3 leaks per year per mile of 3 inch equivalent to one leak per year per 15.5 miles of 3 inch equivalent. This has resulted in a yearly saving of 96 percent of yearly leakage repair expenses for this section.

Pipe placed under protection in 1943 on which the leak was detected and repaired was operated until recently at a potential to remote earth that was lower than that considered satisfactory for complete protection. Another contributing factor that is believed to have considerable influence on the appearance of the leaks on the protected pipes was an increase in operating pressure during the cold weather last winter.

It would appear to be rather significant that nine of the 11 leaks detected this year were found very soon after a general increase in pressure on the system. This would indicate that to obtain full advantage of cathodic protection the main and services should be protected before deep pitting has taken place.

Cathodic Protection Program

Initial Costs

When the relatively large saving in operating expense is considered, it is not readily apparent why cathodic protection is not applied to 100 percent of the distribution system. But if a careful analysis is made, the reason is apparent. Adoption of an extensive cathodic protection program is a major undertaking. Initial costs and man hours required to place all of United Gas' distribution system under cathodic protection is of such magnitude as to make a program of this scope impractical. It is planned, however, to place a relatively large percentage of the system under protection, but at present activities are limited to so-called "hot-spots" and new construction of a sizeable magnitude. United Gas is planning to apply cathodic protection to new distribution systems and large subdivisions at time of installation. There are two major considerations involved in this decision. First and perhaps most important is that by insulating the pipe at time of installation, a considerable saving can be realized. Cost of cathodic protection applied at time of installation of the system is estimated to be less than 2 percent of over-all cost. Second and by no means a minor consideration is the fact that a large percentage of non-standard pipe, such as reclaimed or thin wall pipe is being used. When pipe of this type is considered, any loss of metal may be serious from the standpoint of the operating condition created by leaks in a city distribution system.

Pipe Coating

All pipe being installed now is coated with hot applied coal tar enamel, one wrap of 15 lbs. asbestos felt, and one wrap of 60 lbs. kraft paper. Emphasis is being placed on handling pipe and field coating joints. This is expected to have two beneficial effects. It will, to some extent, prevent major corrosion failures before cathodic protection and limit protective current to a reasonable value when applied. While careful handling and application of pipe line coatings are being stressed, electrical inspection of pipe coating in the field is, in general, not used. It is believed that if major coating faults can be repaired and the joints coated, minor coating faults can be economically taken care of satisfactorily with cathodic protection.

Personnel Training

Perhaps the most discouraging phase of corrosion mitigation is the matter of personnel training. United Gas always has been able to get assistance from competent engineers experienced in this work to do the necessary initial planning and installation, but it has been more difficult to set up an operating organization to maintain the installation. The average gas distribution engineer usually does not possess necessary knowledge, nor does he have the required experience to conduct properly such a program unassisted. The work is highly specialized, and special instruments and equipment not usually found in a gas distribution plant are needed.

This handicap gradually is being overcome by providing field forces with standard instruction on construction, installation, and maintenance of cathodic protection. It is hoped to get the operation of cathodic protection down to the level of the average gas man so he can understand his primary job is to keep his meter insulated and his pipe line free from contacts with the water system.

Engineering Assistance

It planned to leave initial planning, installation instruction and involved maintenance problems for the corrosion engineer, but United Gas believes once field personnel becomes acquainted with the simple fundamentals of cathodic protection, corrosion mitigation problems are well on their way to a satisfactory conclusion.

Acknowledgment

The writer thanks Mr. C. L. Morgan for use of the material originally presented by him and recognizes with appreciation the assistance of Mr. C. L. Woody, Corrosion Engineer of Ebasco Services, for his work in collecting and compiling data and charts appearing in this article.

NACE News

Tentative '49 Conference Technical Program Lists Titles of 41 Papers

Rapid progress is being made in bringing the technical program for the 1949 NACE Conference in Cincinnati to its final form. While some of the articles included in the program hereunder are tentative, it is believed by Dr. N. E. Berry, chairman of the technical program committee and his committeemen that it will be substantially as outlined.

In a good many cases, abstracts and papers already have been received and are in process of review. The quality of material to be presented this year is expected to exceed the high standards set at previous NACE conferences both in timeliness and coverage of the corrosion field.

Following is the tentative program outlined by Dr. Berry:

MONDAY, APRIL 11

SYMPOSIUM ON CORROSION PRINCIPLES

2 p.m.—"Why Metals Corrode," by H. H. Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.

3 p. m.—"The High Temperature Corrosion of Metals," by Hugh J. McDonald, Loyola University, Chicago, Ill.

4 p.m.—General business session.

TUESDAY, APRIL 12

CHEMICAL INDUSTRY SYMPOSIUM

9 a. m.—"The Pulse Polarizer in Corrosion Technology," by Glenn A. Marsh, The Pure Oil Co., Northfield, Ill., and Hugh J. McDonald, Loyola University, Chicago, Ill.

9:40 a. m.—"Physical and Corrosion Characteristics of Lead in the Chemical Industry," by Kempton H. Roll, Lead Industries Association, New York.

10:20 a. m.—"Corrosion Tests in the Processing of Soap and Fatty Acids," by W. Z. Friend, International Nickel Co., New York.

11:00 a. m.—"Plant Corrosion in the Fatty Acid Industry," by R. J. Paul, Emery Industries, Inc., Cincinnati, Ohio.

ELECTRICAL AND COMMUNICATIONS INDUSTRIES SYMPOSIUM

9:00 a. m.—"Corrosion Protection of Power Transformers by Flow Coat Method," by Seibert L. Miller, Union Electric Company of Missouri, St. Louis, Mo.

9:40 a. m.—"Corrosion Testing of Buried Cables," by T. J. Maitland, American Telephone & Telegraph Co., N. Y.

10:20 a. m.—"Field Experience with Corrosion Protection of Galvanized Substation Structures," Seibert L. Miller, Union Electric Company of Missouri, St. Louis, Mo.

11:00 a. m.—"Use of Dry Disc Rectifiers as Valves in Electrolysis Drainage Return Wire," by W. D. Connon, Bell Telephone Company of Pennsylvania, Philadelphia, Pa.

WEDNESDAY, APRIL 13

CATHODIC PROTECTION SYMPOSIUM

9:00 a. m.—"Electrolysis Experiences on a 115-KV High Pressure Oil-Filled Pipe Type Cable Installation in New Orleans," by S. E. Trouard, New Orleans Public Service, New Orleans, La.

9:40 a. m.—"Engineering Aspects of Cathodic Protection as Applied to Pipe Lines," by E. P. Doremus, Cathodic Protection Service, Houston, Texas.

10:20 a.m.—"Cathodic Protection Distribution in Zinc-Steel Systems," by T. P. May and George S. Gordon, International Nickel Co., New York.

11:00 a. m.—"Corrosion Products of Zinc Anodes," by E. A. Anderson, New Jersey Zinc Co., Palmerton, Pa.

PULP AND PAPER INDUSTRY SYMPOSIUM

9:00 a. m.—"Major Corrosion Problems in the Pulp and Paper Industry," by Roy Whitney, Institute of Paper Chemistry, Appleton, Wis.

9:40 a. m.—Round Table Discussion, led by H. O. Teeple, International Nickel Co., New York.

10:20 a. m.—"Corrosion of Digesters and Related Equipment," (author not specified), A. O. Smith Corp., Milwaukee, Wis.

11:00 a. m.—"Non-Metallic Materials and Relation to Pulp and Paper Mill Corrosion Problems," by Carl Richter, Stebbins Engineering and Manufacturing Co., Watertown, N. Y.

GENERAL INDUSTRY SYMPOSIUM

2:00 p. m.—"Field and Laboratory Evaluation of Petroleum-Base Rust-Preventives," by E. L. Walters and R. G. Larsen, Shell Development Company, Emeryville, Calif.

2:40 p. m.—"Erosion - Corrosion of Metals and Alloys," by W. A. Luce and M. G. Fontana, the Ohio State University, Columbus, Ohio.

3:20 p. m.—"Potential Relationships Between Zinc and Iron in Various Natural Waters," by R. B. Hoxeng, Case Institute of Technology, Cleveland, Ohio.

4:00 p. m.—"Corrosion Characteristics of Titanium," by C. H. Permer, Du Pont de Nemours and Co., Inc., Wilmington, Del., and G. E. Hutchinson, Remington Arms Co., Bridgeport, Conn.

TRANSPORTATION INDUSTRY SYMPOSIUM

2:00 p. m.—"Corrosion Aspects of Fusion Welding Aircraft High Strength Aluminum Alloys," by L. W. Smith, Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y.

2:40 p. m.—"Application of Corrosion-Resisting Materials to Railway Electrical Construction," by H. F. Brown, New York, New Haven and Hartford Railroad, New Haven, Conn.

3:20 p. m.—"Electrolytic Corrosion of Steel in Concrete," by G. M. Magee, American Association of Railroads, Chicago, Ill.

4:00 p. m.—"Corrosion of Automobile Bodies," by W. R. Wiers, Fisher Body Division of General Motors Corp., Detroit, Mich.

THURSDAY, APRIL 14

PROTECTIVE COATING SYMPOSIUM

9:00 a. m.—"Porcelain Enamel as a Corrosion-Resistant Coating," by G. H. McIntyre, Ferro Enamel Corp., Cleveland, Ohio.

9:40 a. m.—"Shop Coat Primers for Steel," by S. C. Frye, Bethlehem Steel Co., Bethlehem, Pa.

10:20 a. m.—"Writing Specifications for Organic Metal Protective Coatings," by W. W. Cranmer, Industrial Testing Laboratory, Philadelphia Naval Shipyard, Philadelphia, Pa.

11:00 a. m.—"Cationic Chemical Pretreatment of Metal Surfaces," by W.

NACE MEMBERS

IF You Change Addresses

IF You Change Company Affiliation

IF You Change Positions

Please notify the Central Office NACE, 905 Southern Standard Bldg., Houston 2, Texas, so that you will get CORROSION without delay and that association records can be kept abreast of your progress.

THANKS!

T. Deacon, Solvents and Plastics Co., St. Louis, Mo.

OIL INDUSTRY SYMPOSIUM

9:00 a. m.—"Corrosion in Petroleum Processes Employing Aluminum Chloride," by R. S. Treseder, Shell Development Co., Emeryville, Calif.

9:40 a. m.—(Title unannounced) by E. Q. Camp, Humble Oil and Refining Company, Baytown, Texas.

10:20 a. m.—"Anti-Corrosive Lubricants for Internal Combustion Engines," by A. B. Culbertson, Shell Oil Company, Wood River, Ill.

11:00 a. m. — "Correlation Between Corrosion Survey Results and Actual Conditions," by I. B. Tietze, Phillips Petroleum Co., Hartlesville, Okla.

SALT WATER CORROSION SYMPOSIUM

2:00 p. m.—"Corrosion Resistance of Aluminum and Aluminum Alloys in Sea Water," by William C. Stewart, U. S. Naval Engineering Experiment Station, Annapolis, Md.

2:40 p. m.—"Corrosion of Steel Pipe by Chlorinated Sea Water at Various Velocities," by V. B. Volkening, The Dow Chemical Co., Freeport, Texas.

3:20 p. m.—"Corrosion of Steel Piling in Sea Water," by H. A. Humble, The Dow Chemical Co., Midland, Mich., and others.

4:00 p. m.—"Deterioration of Steel Piling at Palm Beach," by Beach Erosion Board, Washington, D. C.

GAS INDUSTRY SYMPOSIUM

2:00 p. m.—"Cathodic Protection of Gas Distribution Systems," by A. W. Peabody and C. L. Woody, Ebasco Services, Inc., New York.

2:40 p. m.—"Preparation of Reconditioned Pipe Surfaces for Effective Application of Bituminous Coating," by O. C. Mudd, Shell Pipe Line Corp., Houston, Texas.

3:20 p. m.—"The Use of the Thermo Generator for Cathodic Protection," by H. J. Findley, Eaton Manufacturing Company, Cleveland, Ohio.

4:00 p. m.—"Field Tests of Sodium Chromates and Alkalies for Controlling Corrosion in the Gas Condensate Wells," by C. Kenneth Eilerts, Bureau of Mines, Bartlesville, Okla.

Officers of the Northeast Region, NACE, were elected by letter ballot as follows, a report by L. B. Donovan reveals: R. H. Lynch, chairman; N. P. Piefer, vice-chairman; L. B. Donovan, secretary-treasurer.

Northeast Region NACE'S annual report, issued by L. B. Donovan, secretary, lists two meetings in conjunction with local sections, one in Philadelphia December 2, attended by about 100 members and a dinner and evening meeting in New York attended by about 72. Officers of sections are: Metropolitan New York: W. E. Shaw, chairman; T. P. May, vice-chairman; F. J. LeFebvre, secretary-treasurer; Philadelphia: H. L. Hamilton, chairman; A. V. Smith, vice-chairman; E. R. English, secretary-treasurer. Regional officers after January 1, 1949, are: E. P. Noppel, director; R. H. Lynch, chairman; N. P. Peifer, vice-chairman; L. B. Donovan, secretary-treasurer.

The region plans organization of at least two more sections this year, probably in Pittsburgh and Baltimore.

Exhibitors' Displays to Give Complete Picture of Corrosion Control Field

Conference Hotel Reservations Due

Netherland Plaza Hotel reservations for the 1949 National Association of Corrosion Engineers conference in Cincinnati on April 11-14, should be made directly through the hotel by those planning to attend, A. B. Campbell, executive secretary of the NACE advises.

As in previous years, those who arrive on Sunday, April 10 may register for the conference at the Netherland Plaza so they will have this detail out of the way before the formal program begins Monday morning.

Railroads serving Cincinnati already have circularized NACE members, giving details of transportation by rail.

Publicity Sent to Over 100 Publications

In cooperation with W. Z. Friend, chairman of 1949 Conference Publicity Committee and Richard B. Kropf, Cincinnati local publicity chairman, Central NACE office has been actively publicizing the 1949 Conference. Two publicity stories were prepared during December and sent to chairmen for dissemination, and three stories were prepared similarly and sent to the chairmen during January.

Central NACE office also, during January, sent notices about the conference to over 100 publications in the United States and Canada.

Plans for the remainder of the time prior to the conference include sending copies of abstracts of technical papers to all interested publications.

Greater St. Louis Section, NACE, heard Frank E. Dolson, Jr., of the St. Louis County Water Company speak on "Corrosion Problems in the 'Big Inch'" at its December 20 meeting. Mr. Dolson was engineer in charge of corrosion control for the war emergency pipe line during the war. "Evaluation of Corrosion Test Coupons and Their Reliability" was the topic of a general discussion at the meeting.

The Greater St. Louis Section meeting was held at the York Hotel, St. Louis. Regular meeting date of the group is the third Monday of every month.

Directory Corrections

Following are correct listings to be substituted in 1949 NACE directory supplement to January CORROSION:

HOUSTON

RATCLIFF, Van W., Boiler Chemical & Supply Co., Box 5006, Houston 12, Texas.

KELLY, Thomas F. P., James E. Mavor Co., Houston, Texas. For mail: 3511 Corondo Ct.

Exhibits at the 1949 Conference of the National Association of Corrosion Engineers at the Netherland Plaza Hotel in Cincinnati April 11-14 will cover the corrosion control and mitigation and prevention field from anodes to instruments, a survey of the exhibiting companies indicated. Listed among the firms which will show their products and services are some of the largest corporations in the nation, and also some of the smallest firms, whose offerings compare favorably with their bigger contemporaries because they represent ingenious applications for specific purposes.

Visitors viewing exhibits will have the opportunity to see the latest offerings of firms active in the corrosion field, and the chance to talk to company representatives serving at the booths. Personnel of exhibiting firms will have the opportunity to meet personally many of their customers and potential customers. An exchange of valuable information among all attending the conference is assured.

Following is a list of exhibitors as of 3 January 1949:

Allied Chemical & Dye Corp. (Barrett Div.) Aluminum Company of America, American Pipe and Construction Co., American Smelting and Refining Corp., (Federated Metals Div.), Apex Smelting Co.

Stewart R. Browne Mfg. Co., Burgess-Parr Co.

Philip Carey Mfg. Co., Cathodic Protection Service, Cathodic Servicing Co., N. J. Crose Mfg. Co., Crutcher-Rolfs-Cummings.

Dearborn Chemical Co., Dow Chemical Co. (Saran Lined Pipe), Duriron Co.

Ebasco Services, Inc., Electric Railway Improvement Co., Electro Rust-Proofing Corp., Empire Steel Castings.

General Paint Corp. (Hill, Hubbell & Co., Div.), Grip Tite Oil Feld Equipment. Co.

Hills-McCanna Co.

International Nickel Co., Inc.

Johns-Manville Sales Corp., Johnston & Jennings Co.

Koppers Co.

Lebanon Steel Foundry.

Magnaflux Corp., Midwestern Engine & Equip. Co., M. C. Miller, Minnesota Mining & Mfg. Co., Motorola, Inc.

Natasco Co., National Carbon Co., National Lead Co., Nelson Electric Manufacturing Co.

Owens-Corning Fiberglas Corp.

Perrault Bros., Pipe Line Service Corp., Pittsburgh Coke & Chemical Co., Plastic Engineering Sales Corp., Plastic Lining Corp.

Royston Laboratories, Inc., Rust Oleum Corp.

Service Engineers, Inc., Shell Oil Co., Standard Pipe Protection Co., D. E. Stearns.

Tapecoat Co., Tretolite Co.

United Chromium, Inc., U. S. Stoneware.

Westinghouse, T. D. Williamson.

Inter-Society Corrosion Committee Formulated; 21 Affiliates Are Named

Fifteen delegates and three observers from technical organizations concerned with corrosion met October 28, 1949, at ASTM headquarters, Philadelphia, Pa., to formulate the organization of the Inter-Society Corrosion Committee of the National Association of Corrosion Engineers. A plan of organization proposed by Sam Tour, Sam Tour & Co., Inc., ASTM delegate, was adopted. F. L. LaQue, president of NACE, acting as chairman of the meeting, called it to order and appointed C. S. Cole, ASTM alternate delegate, acting secretary.

The new committee's objectives were outlined in part during the meeting as follows:

1. To promote cooperation among various technical societies working in the field of corrosion.

2. To prepare and publish periodically a directory of corrosion workers in the United States.

3. To provide liaison among technical committees of NACE and other technical societies.

4. To act in advisory capacity to technical societies interested in corrosion in an effort to promote progress of all and avoid duplication of effort.

5. To recommend in which society a proposed new activity might be carried out best without, however, attempting to define or limit the field of activity of any society.

6. To stimulate the publication of reliable data on corrosion and to provide publicity for conferences in this field.

Scope Is Widened

The inter-society committee will carry on some activities of the former American Coordinating Committee on Corrosion and the NACE committee on relations with other technical societies, both of which it has succeeded. Significant decisions during the organization meeting included those which a) established the principle that no working subcommittees of the new organization be formed to duplicate work of member societies committees, b) authorized formation of subcommittees covering items cutting across activities of several members, c) instructed members to submit reports during January each year on corrosion activities being carried on or contemplated in their respective societies, d) asked members to keep the committee posted on proposed meetings of their respective societies at which discussion of corrosion would be on the agenda.

Other decisions reached included a provision that the temporary chairman appoint a nominating committee for the offices of chairman and vice-chairman (secretary of the committee is the executive secretary of NACE, under organization rules adopted), and that the form of organization be reviewed after permanent officers are elected and that the next meeting of the committee be held coincident with the NACE 1949 conference during the week of April 11 in Cincinnati.

Membership and Officers

Following are tentative rules relating to membership:

1. Any technical society working actively in corrosion is entitled to appoint two delegates to the committee. These need not be NACE members personally but it is desirable they should be. Delegates' terms of office shall be set by the society represented, but should be at least two but not more than six years.

2. Each United States and Canadian governmental agency actively working in the corrosion field may appoint one observer to the committee.

3. There shall be no other members.

Following are tentative regulations for the selection of officers:

1. Officers shall be chairman, vice-chairman and secretary. Chairman and vice-chairman shall be elected by letter ballot of delegates in even numbered years for a term of two years, shall be from different societies and no society may have a member chairman more than one term in six years.

2. Candidates for office will be named by a nominating committee to be appointed by the chairman not later than January 15 even numbered years. This committee will report in March so elections may be held and officers inducted at the time of the annual NACE meeting.

Annual meetings are to be held at call of the chairman, preferably at time and place of annual NACE conference.

Voting Regulations

Tentative regulations or voting by members are as follows:

1. Each delegate member shall have one vote, which shall be considered as his personal vote, except in changing by-laws, or where otherwise specifically stated in motion.

2. No action taken by ordinary motion shall be considered binding on societies represented.

3. When action representing views of society members is desired, letter ballot will be taken, with each society casting a single ballot on specific authorization by the society voting.

Committee Organization

The main committee will have power to form subcommittees, members of which need not be delegate members of the inter-society or of NACE. Subcommittee reports will be submitted to the main committee. Subcommittee members may attend meetings as observers, without voting privileges.

There shall be no dues.

Suggested activities of the inter-society committee included:

1. Continue work of the former ACCC subcommittee on standard terms and symbols and extend and revise the "Glossary of Terms Used in Corrosion," published in the ECS Corrosion Handbook.

2. Arrange for each member to submit annually a summary of current activities of his society for publication by the committee.

3. To serve as a non-exclusive means of communication with foreign organizations, individuals and member societies.

4. To encourage and advise on courses on principles and practices of corrosion engineering in technical colleges.

5. To assist technical groups in getting authoritative speakers on corrosion.

6. To give advice, when asked, to organizations wishing to undertake or sponsor corrosion research.

The first election held in accordance with the rules of the committee resulted in the choice of the following officers: Dr. H. H. Uhlig, M.I.T., Cambridge, Mass., chairman; Sam Tour, Sam Tour & Co., Inc., New York City, vice-chairman; A. B. Campbell, executive-secretary NACE, secretary ex-officio.

Organizations and Their Delegates Represented on N.A.C.E. Inter-Society Corrosion Committee

As of January 7th, 1949

Alloy Casting Institute, D. W. Talbott, Cooper Alloy Foundry Company, Bloy Street and Ramsey Avenue, Hillside, New Jersey; J. W. Juppenlatz, Lebanon Steel Foundry, Lebanon, Pennsylvania.

American Gas Association, R. F. Hadley, Susquehanna Pipe Line Company, 1608 Walnut Street, Philadelphia 3, Pa.; W. R. Fraser, Michigan Consolidated Gas Company, Detroit, Michigan.

American Society of Mechanical Engineers, S. Logan Kerr, 1528 Walnut Street, Philadelphia 2, Pa.

Electrochemical Society, Dr. H. H. Uhlig, Corrosion Laboratory, Massachusetts Institute of Technology, Cambridge 39, Mass.; K. G. Compton, Bell Telephone Laboratories, Murray Hill, New Jersey.

National Bureau of Standards, Dr. J. G. Thompson, National Bureau of Standards, Washington 25, D. C.

National District Heating Assoc., Leo F. Collins, 2000 Second Avenue, Detroit 26, Michigan.

National Research Council, Dr. F. N. Speller, 6411 Darlington Road, Pittsburgh 17, Pa.; Dr. J. C. Warner, Department of Chemistry, Carnegie Institute of Technology, Pittsburgh, Pa.

American Society for Testing Materials, Dr. C. D. Hocker, Union College, Schenectady 8, New York; Sam Tour, Sam Tour & Co., Inc., 44 Trinity Place, New York 6, N. Y.; Alternate, C. S. Cole, American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

American Institute of Electrical Engineers, L. J. Gorman, Consolidated Edison Company of New York, 4 Irving Place, New York 3, N. Y.;

Dr. H. M. Trueblood, Bell Telephone Laboratories, 463 West Street, New York 14, New York.

Technical Association of the Pulp & Paper Industry, G. F. Pringle, Mead Corporation, Chillicothe, Ohio; C. G. Russell Johnson, Kimberly - Clark Corporation, Neenah, Wisconsin.

American Chemical Society, Dr. G. H. Young, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh 13, Pa.; R. M. Hunter, The Dow Chemical Company, Midland, Michigan.

American Electroplaters Society, K. M. Huston, Armco Steel Corporation, 3400 East Chase Street, Baltimore 13, Maryland; Dr. R. M. Wick, Bethlehem Steel Company, Bethlehem, Pa.

American Association for the Advancement of Science, Dr. H. R. Copson, Research Laboratory, The International Nickel Co., Inc., Linnett Street, Bayonne, New Jersey; W. S. Loose, The Dow Chemical Company, Midland, Michigan.

Association of American Railroads, G. M. Magee, Association of American Railroads, 59 East Van Buren Street, Chicago 5, Illinois; W. F. Collins, Engineer of Tests, New York Central System, 466 Lexington Avenue, New York 17, New York.

American Society of Heating and Ventilating Engineers, Dr. F. N. Speller, 6411 Darlington Road, Pittsburgh 17, Pa.

American Society for Metals, Dr. A. E. White, University of Michigan, Ann Arbor, Michigan; T. S. Fuller, General Electric Company, Schenectady 8, New York.

American Water Works Assoc., H. Lloyd Nelson, U. S. Pipe Company, Burlington, New Jersey; Harry E. Jordan, American Water Works Association, 500 Fifth Avenue, New York 18, New York.

American Foundrymen's Assoc., Dr. J. T. MacKenzie, American Cast Iron Pipe Company, Birmingham, Alabama.

American Institute of Chemical Engineers, Dr. R. B. Mears, Research Laboratory, Carnegie Illinois Steel Corporation, 234 Atwood Street, Pittsburgh 13, Pa.

Federation of Paint & Varnish Production Clubs, Niel T. Phelps, Sinclair Refining Company, P. O. Box 516, Marcus Hook, Pa.; Fred C. Weber, Jr., Phelan-Faust Paint Mfg. Company, 932 Loughborough Avenue, St. Louis, Missouri.

National Association of Corrosion Engineers, Dr. R. B. Mears, Research Laboratory, Carnegie Illinois Steel Corporation, 234 Atwood Street, Pittsburgh 13, Pa.; F. L. LaQue, The International Nickel Company, Inc., 67 Wall Street, New York 5, New York.

The January 17 meeting of the Greater St. Louis Section is scheduled to hear Walter Meyer speak on "The Use and Application of Metallizing in the Prevention of Corrosion." Discussion topic scheduled was "Preparation of Metal Surfaces for Corrosion-Preventing Coatings."

CORROSION PROBLEMS

Questions and Answers for this section should be submitted to L. G. Vande Bogart, Crane Co., Engineering and Research Division, 836 S. Michigan Ave., Chicago, Illinois. All questions will become property of NACE. Those not printed will be answered by mail. Questions should carry sufficient detail to describe the problem. Answers to printed questions are solicited. Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous by request.

No. 8—What are the relative merits of wholly austenitic stainless steel (types 304 and 316) in cast fittings, valves, etc., versus partially ferritic castings of these same alloys when used in severe corrosive environments (dilute sulfuric or hydrochloric acid at 200° F.)?
(Editor's Note: The source from which the above question was received suggests that answers and/or discussion should be based on the assumption that the "severe corrosive environments" involve acid concentrations which yield Ph values in the range of 1.0-3.0 and on the further assumption that substantial quantities of organic [oxygen consuming] material are present at all times.)

No. 9—How is the corrosion resistance of the above and related materials (Question No. 8), in the form of castings, affected by variations in the condition of the exposed surfaces—e.g. machined vs. sand blasted vs. shot blasted vs. electropolished, etc.?

No. 10—What evidence has been accumulated to determine whether graphitic and/or metallic wire woven packing materials are responsible for corrosion of steel pump shafts due to galvanic action? What regularly available packings do not cause or affect the corrosion of shaft materials either in storage or during stand-by conditions or while the pump is in service?
(Editor's Note: The term "steel pump shafts" as used above should be interpreted to include carbon steel, low alloy steel, and stainless steels.)

No. 11—What methods are used to repair corroded cast iron equipment in the field? How may this equipment be repaired to useful status and maintained so?

No. 12—(A) How can "bacterial" corrosion be identified: 1) to make certain that microoganisms are responsible; 2) to determine which types are responsible? (B) If microorganisms are responsible for the corrosion, what preventative measures can be recommended?

No. 13—Does the "N.D.H.A." Corrosion Tester" provide a reliable index as to the corrosivity of return condensate? Can it also be used to provide an index as to the corrosivity of recirculating cooling waters and/or to indicate the effectiveness of corrosion inhibitors offered for use with such waters?

Technical Practices Group Heads Named

An expanded field of inquiry has been assigned to TP-1, the Committee of Oil and Gas Well Production Equipment (formerly Condensate Well Corrosion Committee) following the substantial completion of its original task. Walter F. Rogers, Gulf Oil Corporation, Houston, chairman of the committee, now is awaiting a decision with respect to publication of the findings of the condensate well inquiry, and some indication of the next problem his group will investigate.

K. G. Compton, of the Murray Hill Laboratory, Bell Telephone Laboratories, Murray Hill, New Jersey, has been named chairman of TP-13, the Committee on Annual Loss Due to Corrosion. Mr. Compton already has independently made inquiries in this field, but it is believed particularly important to collect comprehensive data on corrosion losses so that the full implications of the corrosion control problem may be realized.

Other Technical Practices Committees, and their chairmen as of December 29, 1948 are as follows:

TP-2—GALVANIC ANODE. M. C. Miller, Ebasco Services, Inc., Two Rector Street, New York 6, N. Y.

TP-3—ANODES FOR IMPRESSED CURRENTS. Donald H. Bond, The Texas Pipe Line Co., Houston, Texas.

TP-4—MINIMUM CURRENT REQUIREMENTS FOR CATHODIC PROTECTION. A. V. Smith, 370 Trevor Lane, Bala-Cynwyd, Pa.

TP-5—CORROSION PROBLEMS INVOLVING HANDLING CHEMICALS. Mars G. Fontana, Ohio State University, Columbus, Ohio.

TP-6—PROTECTIVE COATINGS. George Seagren, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.

TP-7—MATERIALS FOR USE AT HIGH TEMPERATURES. H. A. Scheill, Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis.

TP-8—CORROSION PROBLEMS INVOLVED IN HANDLING INLAND WATERS. V. V. Kendall, National Tube Co., Frick Bldg., Pittsburgh, Pa.

TP-9—PREVENTION OF CORROSION BY MEANS OF INHIBITORS. A. Wachter, Shell Development Co., 4560 Kerton St., Emeryville, Cal.

TP-10—CORROSION FATIGUE TESTING. V. V. Kendall, National Tube Co., Frick Bldg., Pittsburgh, Pa.

TP-11—IDENTIFICATION OF CORROSION PRODUCTS. No chairman.

TP-12—ELECTRICAL GROUNDING PRACTICES. H. L. Hamilton, Keystone Pipe Line Co., 260 S. Broad St., Philadelphia, Pa.

Western Region Is Active During 1948

Wide interest in the activities of the Western Region during 1948 is underlined in the report of activities of the region issued by Irwin C. Dietze, chairman. At the four dinner meetings held by the region during the year there were present 122 guests, while an attendance of 129 members was reported, an average of 30 guests a meeting and 32 members.

Topics of wide variety and profitable discussions featured both the regional and San Francisco Bay Area Section activities, also reported by Mr. Dietze. The report was as follows:

OFFICERS

Irwin C. Dietze, chairman, Department of Water and Power, City of Los Angeles.

C. Kenyon Wells, vice-chairman, Long Beach Water Department, City of Long Beach.

Chris. A. Goldkamp, secretary-treasurer, San Diego Gas and Electric Co., San Diego, Cal.

Four dinner meetings were held, at Roger Young Auditorium, 936 West Washington Blvd. ,Los Angeles, Cal., at 6:30 p.m., as follows:

February 4th, 1948: Agenda included Progress report on domestic hot water heater corrosion being conducted by the City of San Diego Water Department, by Roy E. Dodson, Jr., sanitary engineer; latest developments and use of magnesium for cathodic protection of water heaters and pipe lines, etc., by Arthur Smith, Jr., manager Cathodic Protection Sales, of the Dow Chemical Company, Midland, Michigan, who was visiting the West Coast; "Corrosion Problems Related to Industrial Waters and Methods of Prevention" with a 16-mm color picture of valve reconditioning at Atlanta, Georgia, by A. R. Guenther, Dearborn Chemical Company.

There were 36 guests and 30 members in attendance at this meeting.

May 12, 1948: Agenda included "Plastic Coatings and Corrosion," a discussion of different types of plasticmaterials for use in protective coatings and their means of application, by Charles G. Munger, chief chemist, Amercoat Division, American Pipe and Construction Co., Los Angeles. The above paper was published in the October 1948 issue of Corrosion magazine.

"Some Notes on Corrosion in Power Plants," by John F. Mason, Jr., corrosion engineer, Development and Research Division, The International Nickel Co., Inc., New York.

There were 39 guests and 31 members in attendance at this meeting.

September 8, 1948: Agenda included "The Application of Carbon and Graphite for Cathodic Protection Anodes," by H. M. Rutledge, National Carbon Co., Inc. Mr. Rutledge also read a paper by Mr. J. P. Oliver entitled "The Value of Backfill With Carbon and Graphite Anodes;" sixteen mm color motion picture showing installation of vertical anodes by Escondido Mutual Water Co., Escondido, California, by Enoch C. Rogness, corrosion engineer, Water Department, City of San Diego, California.

There were 18 guests and 33 members in attendance at this meeting.

December 1, 1948: Agenda included "Marine Fouling and its application to circulating sea-water tunnels, heat exchanger equipment, condenser tubes, metal piling, ship bottoms, etc., by Dr. Dennis L. Fox, Professor of Marine Biochemistry of the University of California, Scripps Institute of Oceanography at La Jolla, California, followed by a panel discussion among E. R. Stauffacher, Southern California Edison Co., H. A. Todhunter, Dept. of Water and Power, Leon J. Willien, San Diego Gas & Electric Co., J. A. Kavenaugh, Revere Copper and Brass, Inc., J. I. Richardson, American Pipe & Construction Co.

There were 29 guests and 35 members in attendance at this meeting.

Other meetings were held as follows:

May 3, 1948: Joint meeting as the guests of the American Institute of Mining and Metallurgical Engineers, Metals Group, at the Ethyl Corp., Auditorium, West Fifth and Beaudry Avenues. Subject, "Symposium on Corrosion."

June 21, 1948: Committee appointed by F. A. Hough, director of Western Regional Division at the request of the president, Mr. F. L. La Que, to consider suggestions to improve the procedure for nominating and electing National officers was as follows: F. A. Hough, Chairman; Irwin C. Dietze, C. Kenyon Wells, Chris. Goldkamp, E. O. Kartinen.

September 17, 1948: Meeting of the Board of Trustees of the Western Regional Division. Nominating committee appointed was C. Kenyon Wells, chairman; Vance Jenkins and Dave T. Jones.

October 1, 1948: Meeting of the Board of Trustees, followed by a regular business meeting of the Western Regional Division. The following were nominated for the year 1949: Chairman—H. J. Keeling, Southern Counties Gas Co. of California; Vice-Chairman—E. O. Kartinen, Signal Oil and Gas Co.; Sec.-Treas. —E. R. Stauffacher, Sou. Calif. Edison Co.; Regional Director—Irwin C. Dietze, (3 year term) Department of Water & Power, City of Los Angeles.

December 1, 1948: Meeting of the Board of Trustees before the regular dinner meeting.

Letter ballot was mailed to each member of the Western Regional Division to be returned by midnight of November 1, 1948. Seventy-nine ballots were received by the nominating committee, T. H. Gilbert, F. O. Waters, and Floyd E. Brodley, the results of which elected the above mentioned officers.

December 17, 1948: Meeting of the Board of Trustees with the newly elected officers for the coming year. Secretary-treasurer's records were turned over to the new officer, E. R. Stauffacher.

San Francisco Bay Area Section OFFICERS

A. Wachter, chairman, Shell Development Co., Emeryville, California.

Peter C. Jurs, vice-chairman, Shand & Jurs Co., Berkeley, California.

William R. Schneider, secretary-treasurer, Pacific Gas and Electric Company.

The following meetings were held during the year:

February 3, 1948: Agenda included "Corrosion Tuberculation Studies with San Francisco Water," by Edwin W. Barber, San Francisco Water Department; "Corrosion Prevention by Dehumidification," by M. J. Gigy, Cargocaire Engineering Corp.

April 6, 1948: Agenda included "Corrosion Inhibition of Water," by O. E. Morrow, Hall Laboratories; "Electrical Protection of Pipe Lines," by W. R. Schneider, Pacific Gas and Electric Co.

June 15, 1948: Agenda included "Corrosion Prevention on the San Francisco Bay Bridge," by H. C. Snead and C. S. Hamilton; 16-mm sound film on Application and Benefits of Hot Dip Galvanizing, by the Hot Dip Galvanizers Assoc.

October 12, 1948: Agenda included "Marine Corrosion," by Captain H. A. Ingram, the Planning Officer, San Francisco Navy Yard; Corrosion Clinic—General discussion on corrosion problems informally presented by members.

December 7, 1948: Agenda included "The Inter-relation Between Microbiological Deposits and Corrosion," by W. J. O'Connell, Jr.; Corrosion Clinic—General discussion on corrosion problems informally presented by members.

Western Regional Division officers elected by letter ballot to serve during 1949 are as follows: Harry J. Keeling, chairman; Ernest O. Kartinen, vice-chairman; E. R. Stauffacher, secretary-treasurer; Irwin C. Dietz, regional director.

San Francisco Bay Area Section officers for 1949 were elected as follows: Robert T. Effinger, Shell Oil Co., Inc., Martinez, Calif., chairman; Richard S. Treseder, Shell Development Co., Emeryville, Calif., vice-chairman; Arthur E. Storm, Tidewater-Associated Oil Co., Avon, Calif., secretary-treasurer.

President W. V. Houston of Rice University addressed a joint meeting of the Houston chapters of AIEE and ASME December 8 at the Houston YMCA. Dr. Houston proposed that college engineering courses be revised to give the engineer a background of many other kinds of work, with specialized engineering studies to follow on the graduate level and with most practical learning to be done "on the job." A period of apprenticeship comparable to internship for medical graduates also was proposed by Dr. Houston. Dr. F. C. Bolton, Texas A. & M. College president, introduced Dr. Houston.

PERSONALS

Dr. William Lee Davidson, an international authority on atomic energy, has been named director of The B. F. Goodrich Company's physical research department, it is announced by Dr. Howard E. Fritz, B. F. Goodrich vice-president in charge of research. Dr. Davidson, a graduate of William and Mary College in Virginia, his birthplace, and Yale University where he received his doctor's degree, has been with B. F. Goodrich since 1940. He is the co-author of a textbook on nuclear physics now in its tenth printing and widely used in major colleges and universities. The rubber company scientist went to the government atomic energy project in Oak Ridge, Tennessee in 1947 and returned to Ohio before the new B. F. Goodrich Research Center at Brecksville, Ohio began operation in June, 1948.

Dr. Kent R. Van Horn, chief of the Cleveland branch of Aluminum Research Laboratories since November, 1945, has been named an assistant director of research for the company. **Maurice W. Daugherty,** assistant chief of the Cleveland Laboratories during the same period succeeds Dr. Van Horn as chief. Both appointments became effective January 1.

Considered one of the nation's outstanding metallurgists, and an authority in the field of industrial x-ray, Dr. Van Horn will remain in Cleveland. Here, he will continue to devote his talents to the improvement of Alcoa casting and forging processes and alloys, the special function of the Cleveland research division.

Mr. Daugherty, similarly prominent in metallurgical circles, and in research into the corrosion of light metals, will supervise laboratory staff work. Mr. Daugherty has earned recognition for blueprinting a corrosion testing laboratory and test procedures for determining the corrosion resistance of light metals. He is a member of the National Association of Corrosion Engineers, the American Society for Metals, and the American Institute of Mining and Metallurgical Engineers.

William J. Tobin has been appointed sales representative for the Dearborn Chemical Co., Chicago, Ill., in the Minnesota territory. Roy O. Benson, for eleven years a member of Dearborn's research staff, has been assigned as sales representative to the Chicago territory. E. W. Houseknecht has been appointed Dearborn sales representative in Wisconsin, making his headquarters in Appleton, Wis. E. Stewart Carlson has been added to the advertising staff of the Dearborn Company. He formerly was with the Chicago Tribune.

Dr. George E. Ziegler has been named director and Dr. Clayton O. Dohrenwend, assistant director of the Midwest Research Institute. Dr. Ziegler is known for his experimental X-ray diffraction studies and Dr. Dohrenwend is a specialist in the field of engineering mechanics and past president of the Society for Experimental Stress Analysis.

William O. Ray, consulting electrical engineer, has opened offices at 1211 Union National Bank Bldg., Houston 2, Texas.

NEW PRODUCTS

Materials – Service – Literature

Director of research, a new position in the Signal Corps, will be filled by Dr. Harold A. Zahl, physicist, Brig. Gen. F. H. Lanahan, acting for the chief signal officer, has announced. Dr. Zahl's responsibilities will cover research conducted within Signal Corps' laboratories and in an external program in universities and industry. Activities headquarters will be Fort Monmouth, N. J.

New environment for the "greatest coal-producing area in the world" is one of the objectives of a research fellowship established by Western Pennsylvania Coal Operators Association at Mellon Institute. Investigations into reactions of coal and inorganic sulfides, especially at low temperatures, are to be headed by Dr. Wiliam L. Nelson, who has been with the institute since 1926.

National Conference and Exhibit of the Instrument Society of America for 1949 will be held at St. Louis, Mo. September 12-16, 1949 and in Buffalo, N. Y., September 11-15, 1950, the board of directors of ISA announced following a recent Philadelphia meeting.

A Long-Range investigation of major problems in the technology of fine wire products, such as tire bead wire, strand for heavy-duty tire casings, music wire and aircraft and textile wires has been instituted under an industrial fellowship at Mellon Institute by The National-Standard Company, Niles, Mich. Charles T. Wilkins (V.M.I., BS, Chemistry, 1942; Pittsburgh U., MS, 1946), formerly metallurgist with the Copperweld Steel Company, will head the project.

The Instrument Society of America will meet May 12-13, 1949, at Toronto, Canada. Scheduled are four technical sessions of interest to engineers engaged in measurement, inspection, testing and automatic control.

Temflex 105, a new plastic tubing, designed for continuous use at temperatures up to 105° C. and approved by Underwriters' Laboratories for such service is being marketed by Irvington Varnish & Insulator Co., Irvington, N. J. The company claims the new tubing gives favorable results in regard to retained elongation, tensile strength, flexibility and dielectric strength after exposures to temperatures up to 150° C. Tests of 1000 hours exposure at 105° C. to Wemco transformer oil shows little deleterious effect, the company says.

Gas-Phuse, a new automatic gas shut-off designed for installation in high pressure gas service lines outside buildings is announced by Ernest C. Lundt, Inc., Route 6, Little Falls, N. J. The device is all-metal, has no springs or moving parts, is furnished in its own fitting style body of cold rolled steel or may be inserted into the gas service line and expanded into the pipe. Installation position is not critical and set flows are affected approximately 10 percent by vertical positions. The horizontal run will be customary.

Hastelloy and Multimet alloy drawn wire, for welding, metal spraying and wire screen and springs is now available in sizes down to 0.060 inch in diameter from Haynes Stellite Company, Kokomo, Indiana. The wire is available in coils or in cut and straightened lengths, bare or flux-coated. Sizes below 0.060 inch are supplied by Kelmet Laboratories Co., Madison Ave. and West 117th St., Cleveland, Ohio.

An Improved electronic phase meter is announced by the National Bureau of Standards. The instrument is considered well adapted to serve as standard test equipment in industrial laboratories. (Technical Report 1217)

Microwave Measurement standards are being intensively developed at the National Bureau of Standards in the range of 300 to 100,000 megacycles and above. (Technical Report 1309)

Canadian Nickel deliveries in all forms are expected to set a new peacetime record in 1948, a release of the International Nickel Co. of Canada, Ltd., Copper Cliff, Ont., announces.

De-ionizing systems to produce pure water at low cost are outlined in a new 20-page publication of the Dearborn Chemical Co., Chicago, Ill. Copies are available on request.

Solids Interceptor to prevent fragments of solids present in waste water from flowing into building drainage lines is announced by J. A. Zurn Mfg. Co., Erie, Penna.

Viscosity Controller and recorder which is said to make all measurements, record them, add solvent as needed, control temperature and even empty and fill reactor vats if necessary is announced by Westinghouse Electric Corporation, 306 Fourth Ave., Pittsburgh 30, Penna. Recording is on a circle type graph. Simple additions will adapt the instrument to perform many other operations, the manufacturers claim.

Ion-exchange resins are used for chemical filtration of water in new water demineralizers made by Ion Exchange Dept., Industrial Filter & Pump Mfg. Co., 1621 W. Carroll Ave., Chicago 12, Ill. Sizes with capacities from five to 1000 gallons per hour are available.

Dominion Magnesium, Ltd., has established its head office, sale and technical service departments at Suite 1505, Canada Permanent Bldg., 320 Bay Street, Toronto 1, Canada.

Apexior No. 1, a surfacing material for boilers and power and processing equipment in wet-heat service, is explained in Bulletin 1530, available on re-

NEW PRODUCTS

Materials – Service – Literature

quest from The Dampney Co. of America, Hyde Park, Boston 36, Mass. Manufacturers claim the material, when deposited on the surface of clean steel, isolates the metal from corrosive materials in boiler water. It also is claimed that deposits do not bond chemically with the material.

Branson Instruments, Inc., has taken up new quarters at 436 Fairfield Ave., Stamford, Conn. The firm manufactures the "Audigage" thickness tester, "Coatingage" measuring device and an electrical pipe caliper.

Lining Acid and alkali storage tanks, or those carrying sour crude and salt water, tubular material used in salt water disposal, drill stem and casing in wells producing corrosive materials, and coating pipe outside are among the services offered by Corrosion Engineering Co., 1814 West Richmond, Houston 6, Texas. The firm, headed by Allen D. Stafford, offers rust protection on a long-range predetermined cost-factor basis. Inquiries are invited.

Rust-Preventive wrappings of metal parts, which in many cases, the manufacturer claims, eliminates the need for liquid or grease rust preventive coatings is being offered by the Nox-Rust Chemical Corp., 2419 S. Halstead St., Chicago 8, Ill. The wrapper is described as an essentially neutral paper from which an odorless, non-toxic vapor is emitted to protect the metal parts it covers. Descriptive literature is available on request.

Heat Generated by resistance of boiler water between solid metal electrodes is a feature of Speedylectric steam generators—1½ hp boilers available in 100 psig, 200 psig and 250 psig, and operating on 220-volt single phase power. The units are 14 x 21 x 35 inches and weigh less than 100 pounds. Livingstone Engineering Company, 100 Grove Street, Worcester 5, Mass., builds the boilers to ASME code.

Stainless Steel pigments and surface finishing materials recently announced include: Charles Hardy, Inc., 420 Lexington Ave., New York 17, N. Y.—18-8 Type 302 flake 100 percent minus 200 mesh. Dry flake contains about one percent stearic acid as a leafing medium; the paste contains about 25 percent Varsol as a paste forming agent. "Liquid Stainless Steel," a new product developed by the plastics division of the Lockrey Company, can be applied like paint to any surface, manufacturers claim. Beauty and durability, combined with water, heat and chemical resistance of plastic is claimed for the product.

A Copolymer of styrene and alkyd, developed by the American Cyanamid Company for fast drying enamels, has been named "Cycopol."

A New B. F. Goodrich plant at Avon Lake, Ohio, will produce plasticizers for vinyl and other synthetic resins.

Calgon's "Banox," described as an amorphous metaphosphate compound, is used by Jones and Laughlin Steel Corp. as a rust inhibitor and lubricant, permitting an increase of 20 to 25 percent in speed of drawing fine high-carbon wire, the company reports.

Karbate Brand pipe and fittings are catalogued by National Carbon Co., Inc., 60 E. 42nd St., New York 17, N. Y., in Section M-8800B.

A 38-page booklet entitled "Vinylite Resins and Plastics" is available from Bakelite Corp., 30 E. 42nd St., New York 17, N. Y.

Titleflex, Inc., Newark, N. J., manufacturers a double-interlocking, stainless and corrosion-resistant nickel alloy flexible tubing for working pressures up to 7000 psi and 900° F. Monel for the tubing is supplied by Driver-Harris Company, Harrison, N. J.

General Electric's metallurgy division, chemical department, is making available for various uses a tungsten, nickel, copper alloy produced by powder metallurgy. "Hevimet" has a density 50 percent greater than lead and was developed originally as a screen against radium and X-rays.

NEW CORPORATE AND ASSOCIATE MEMBERS

Following is a list of new Corporate and Associate members who have joined NACE during the period from December 15 to January 15, 1949, bringing to 260 the number of these types of sustaining Association memberships:

Anderson Brothers Corp., Houston, Texas	W. A. Rose
Bridgeport Brass Co., Bridgeport, Conn.	C. L. Bulow
Metropolitan Water District of Southern California, Los Angeles, Cal.	Julian Hinds
Morrison Construction Co., Inc., Austin, Texas	E. G. Morrison
Oklahoma Natural Gas Co., Tulsa, Okla.	C. E. Cloud
New York Central Railroad, New York City	D. B. Thompson
Standard Pipeprotection Co., Inc., Brentwood, Mo.	Hugh W. Baird
Tret-O-Lite Company, Webster Groves, Mo.	Dr. Charles M. Blair

CORROSION LITERATURE

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For Sale by NACE

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Management Information on Cathodic Protection of Buried Metallic Structures Against Corrosion

Bulletin 1, Prepared by Correlating Committee on Cathodic Protection.
In Lots of 10 or more, each.....10c

Bibliographic Survey of Corrosion, 1945

Abstracts of Corrosion Literature for the Year 1945 Compiled by Robert D. Misch, James T. Waber and Hugh J. McDonald, indexed and cross indexed. Cloth-Covered, Bound Book.
Single copy postpaid to members of the Association.....$4.00
To non-members of the Association 5.00

Control of Pipe Line Corrosion

Prepared by O. C. Mudd, Chief Corrosion Engineer, Shell Pipe Line Corp. Paper Bound, Manual, 6" by 9".
Single copy postpaid.....$1.25
Five or more copies to one address, postpaid at $1.00 per copy.

Directory

Compiled by American Coordinating Committee on Corrosion.
Single copy postpaid.....$2.00

Proceedings First Annual Meeting

Of the National Association of Corrosion Engineers, held in Houston, Texas, April 10 to 12, 1944.
Single copies postpaid to members of the Association.....$3.00
To nonmembers of the Association 6.00

☆

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Corrosion Abstracts

ATMOSPHERIC

The Corrosion of Aluminum Is Shown in the Return of Eros. *Light Metal Age,* 7, 6-9, 26. (1948) Apr.

Results of close examination of the condition of above famous statue located in London are described and illustrated. Details of its condition after 54 years' exposure, of some little known features in its construction and assembly, of certain repairs and renovations effected prior to reinstatement, and of the method employed to clean the deposited grime from the aluminum surface to reveal the true character of the underlying patina, are presented.—BLR.

Effect of Surface Finishing of Non-Ferrous Base Metals on the Protective Value of Plated Coatings. G. J. Kahan. Annual Report on A.E.S. Res. Project 4. Paper before Amer. Electroplaters' Soc. 34th Ann. Convention, 1947 *Proc. AES,* 298-300 (1947) June.

Details of projected tests, to be made on rolled and cast brass and on zinc-base diecastings, bright-nickel and chromium-plated to standard specification requirements with a copper undercoat in the case of the zinc-base materials. Methods used for surface-finishing the basis materials will be mechanical, electrochemical and chemical. Three exposure sites will be used, representing rural, industrial and marine atmospheres.—INCO.

Effect of Atmospheric Corrosion on Maintenance and Economics of Overhead Line Hardware and Guy Strand—Part I. C. J. Couy. *Corrosion,* **4,** 133-140 (1948) Apr. **Part II,** 207-218 (1948) May.

Part I outlines results of an engineering study of the aging or "wearing" characteristics of component materials and of application to the problem of the information so secured. Deals with protection afforded by various metallic coatings, as well as with corrosion of the different ferrous alloys used.

Part II discusses considerations of the effect of corrosion decay on structural strength. Includes numerous illustrations showing effect of different periods of exposure on the above. Gives charts and equations for determining optimum cross-sectional dimensions and optimum frequencies of inspection. (To be concluded.)—BLR.

Report of Sub-Committee II (of A.S.T.M. Committee B-8) **on** (Atmospheric Exposure) **Performance Tests** (of Copper, Chromium, Nickel, and Lead Deposits on High-Carbon Steel). *Amer. Soc. Test. Mat.* Preprint No. 15, 3-70, (1947).

Based on preliminary exploratory atmospheric-exposure tests of various combinations of copper, nickel, and chromium coatings on high-carbon steel, a more extensive series of coatings was exposed at five locations. Results to date show that the thickness of the nickel, not that of the copper coating, is the determining factor in composite coatings. A summary of inspection observations is given on the atmospheric corrosion of electroplated lead coatings at four locations. The earlier trends indicate that electroplated lead is more protective at New York than at Kure Beach, and that superior performance results when using a copper flash under the lead. Details of corrosion losses and penetration are given, and the data show that the weathering rate of the lead in Pennsylvania, Honduras, and at Kure Beach and New York, is 0.000074, 0.000075, 0.000088, and 0.000033 inch, respectively, per year. The corrosion rate of the lead is greater when it is deposited on the copper plate than when deposited directly on steel, and bears an inverse relation to the protective value of the coatings exposed to the same atmospheres.—MA.

BEARING

Engine Lubricating Oils — Equipment and Methods Employed at Thornton Research Center. *Auto. Eng.* **38,** No. 499, 97-105 (1948) March.

Necessity to tackle piston ring sticking and bearing corrosion in high speed diesel engines from the lubricating oil angle is discussed.—INCO.

Fretting Corrosion—How to Eliminate It. E. V. Albert, The Texas Company, *Steel,* **122,** No. 14, 72-6 (1948) Apr. 5.

"Fretting corrosion" or "friction oxidation" is a corrosion phenomenon which occurs in the contact areas of loaded metal surfaces subject to oscillatory or vibrating motion, e.g. automobile wheel bearings during rail or highway transport. Fretting corrosion is primarily mechanical and depends on load, motion and the presence of oxygen. A reddish-brown iron oxide deposit is usually produced. The corrosion can be reduced by submergence of contact areas in low-viscosity, fluid lubricants having high film strength, strong adhesive and extreme pressure properties, and high resistance to oxidation and deterioration. However, lubrication does not eliminate the corrosive effects of load and motion.

CATHODIC PROTECTION

Magnesium for Cathodic Protection of a Municipal Piping System. K. D. Wahlquist and Oliver Osborn, *J. of the American Water Works Assoc.,* **40,** 495-503 (1948) May.

Discusses ability of magnesium to halt corrosion, theory and practice of its use, its natural advantages and its economic aspects, based on observations of a proven installation at Lake Jackson, Tex.—BLR.

Cathodic Protecton of Steel Surfaces in Contact With Water. Leon P. Sudrabin. *Water & Sewage Works,* **95,** R109-R121 (1948) Apr.

Describes fundamental principles, recommended procedures and some test results showing effects of different factors. 44 ref.—BLR.

Magnesium Anodes for Protecting Water Heaters and Storage Tanks (Galvanized). Anon, *Modern Metals,* **4,** No. 2, 32-34 (1948) March.

Describes briefly some general measures for reducing galvanic corrosion, and gives the results of tests on the effectiveness of cathodic protection of galvanized hot water tanks by magnesium anodes, showing methods of fitting. See also articles by J. B. Bialosky on cathodic protection of hot-water tanks and on corrosion of hot-water tanks.—BNF.

Cathodic Protection of Steel in Hot Water by Alloys of Magnesium, Zinc,

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

AER	*Aeronautical Review,* Institute of Aeronautical Sciences, Inc.
ALL	*The Abstract Bulletin,* Aluminum Laboratories, Ltd.
AWWA	*Journal,* American Water Works Association
BLR	*Battelle Library Review,* Battelle Memorial Institute Library
BNF	*Bulletin;* British Non-Ferrous Research Association
CALCO	Calco Chemical Division, American Cyanamid Corp.
CE	*Chemical Engineering,* McGraw Hill Publishing Co.
CEC	Consolidated Edison Co. of New York, Inc.
EW	*Electrical World,* McGraw Hill Publishing Co.
GPC	General Petroleum Corp. of California
INCO	The International Nickel Co., Inc.
IP	Institute of Petroleum
MA	*Metallurgical Abstracts,* Institute of Metals, London, Eng.
MR	*Metals Review,* American Society of Metals
NBS	National Bureau of Standards
RA	*Refrigeration Abstracts,* American Society of Refrigeration Engineers
RM	*Revue de Matallurgie,* Paris, France
RPI	*Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries,* Research Association of British Paint, Colour & Varnish Manufacturers, London.
TDD	*Technical Data Digest,* Air Materiel Command—Technical Service Section
UOP	Universal Oil Products
No Code	*Current Technical Literature,* Bell Telephone Laboratories

and Aluminum. R. R. Rogers and G. E. Viens, *Canadian Mining and Metall. Bull.*, 216-224 (1948) Apr. *Transactions*, **51**, (1948).

The degree of cathodic protection of steel and the anode-corrosion rate were determined for anodes and waters of different compositions at temperatures similar to those in domestic hot-water tanks. Twenty different anode materials, 16 of them magnesium-zinc-aluminum alloys, were immersed in different synthetic waters resembling those to be found in various parts of Canada. Results are tabulated, charted, illustrated, and discussed.—BLR.

Cathodic Protection of Steel Tank Bottoms by the Use of Magnesium Anodes. J. R. James and R. L. Featherly, *Petrol. Technol.*, **10**, No. 3 (1947), *A.I.M.M.E Tech. Publ.* No. 2202, 7 pp.

Details are given of the size, number, and distribution of magnesium anodes required for cathodically protecting a 20,000 bbl. storage tank bottom from external corrosion. Current and potential measurements before and after installation of the anodes are given. The annual installation cost, spread over 15 years' expected life, is about $20, which amounts to 1 percent or less of the cost of replacing the tank bottom.—MA.

Cathodic Protection of Casings in Loudon. Pool. S. P. Ewing and J. F. Bayhi, Carter Oil Co. Paper, NACE, St. Louis, Apr. 5-8, 1948; Abst. *Oil & Gas Jr.*, (1948) Apr. 8, **46**, No. 50, 92 (1948) Apr. 15; *Corrosion*, **4**, 264-286 (1948) June.

The first casing leak in Loudon pool occurred in 1944, about seven years after its discovery. The leak rate increased until 1946 when use of electrical insulation between flow lines and casings greatly reduced the rate. Measurements were made to determine whether cathodic protection would further reduce the leaks. Current required to protect casings was made by two methods: 1) by IR drop measurements along the casings, and 2) by current-potential curves of the external surface of the casing. Protection of a 1500-ft. casing by 1.50 amp. of current was indicated.

Discussion of Paper by D. B. Good: "Location and Selection of Anode Systems for Cathodic-Protection. (Units)." R. A. Brannon, O. C. Mudd. *Corrosion*, **3**, No. 12, 632-635 (1947).

M. gives anode-to-soil resistance data for a composite bed of anodes, and points out the danger of relying on calculation where conditions are irregular and the qualifying factors of a formula cannot be determined.—MA.

Author's Reply to Discussions of Paper: Location and Selection of Anode Systems for Cathodic Protection. D. B. Good, *Corrosion*, **4**, 185-186 (1948) Apr. —BLR.

Cathodic Protection of Steel in Sea Water With Magnesium Anodes. R. A. Humble, *Corrosion*, **4**, No. 7, 358-70 (1948) July.

Magnesium anodes are shown to perform satisfactorily when used for the cathodic protection of steel in sea water. Solution potentials of —1.5 v (versus saturated calomel electrode) are observed; these are practically independent of time and the magnitude of the current flow. Recoveries of 500 to 600 amp. hr/lb. of metal consumed are realized. Sand-blasted steel is shown to require in excess of 10 ma/sq. ft. for initial protection, although protection may be eventually achieved by a fixed current density of approximately 6 ma/sq. ft. Rusted steel can be protected at a slightly lower current density. Protection can be effected at current densities as low as 3 ma/sq. ft. by the application of a high initial current density (50 ma/sq. ft.) to achieve immediate polarization. The high initial current requirements with respect to time.—TDD.

CHEMICAL

Corrosion of Metals by Hydrochloric Acid at High Temperatures. Kh. L. Tseytlin, *Zh. Prikladnoy Khimii*, **21**, No. 1, 35-41 (1948) Jan.

Loss-in-weight tests on mild steel, 26 percent chromium steel, cast iron and copper in hydrogen chloride (wet and dry) at temperatures up to 500° C.—BNF.

A Note on the Corrosion of Lead by Blended Mineral Combing Oil. W. L. Thomas and E. W. Clark, Woolcombers, Ltd., *Textile Inst. J.* **38**, 593 (1947) Dec.

The oleic acid contained in blended mineral wool-combing oil may attack lead with formation of soaps which deposit on the wool causing stickiness and discoloration. An occurrence of this where the oiling mechanism included a tank and trays made of lead-coated steel sheet is reported. The blended oil was found not to attack iron, steel, or tin-plated steel and these should therefore be used instead of lead-coated steel in the oiling equipment.

The Mechanism of Corrosion on Fatigue of Steel in Acid Solution. Simnad M. Tchorabdji and U. R. Evans, *J. Iron and Steel Inst.*, **156**, Pt. 4, 531-539 (1947) Aug.

Corrosion fatigue in hydrogen chloride shows certain analogies to, but also marked differences from, that in potassium chloride. At the end of an incubation period, rounded pits developed into cracks, the residual strength sharply declined, the rate of chemical corrosion (hitherto constant) greatly increased, and the potential dropped. These four changes occur sooner at high than at low stress ranges. A cathodic current can prevent detectable chemical attack but does not greatly increase life. Results are explained best by the changes produced by stress within the metal, in contrast to a rupture of films, which often may be important in neutral solutions. 23 references.—INCO.

Aluminum Cans. D. Nichelsen, *Modern Packaging*, **21**, 134-137+ (1948) Apr.

Describes and illustrates use of the above for food packaging in Norway. Advantages and limitations are outlined and storage life for various foods as determined by experiment is tabulated. Use of surface protection to prevent corrosion is required for certain types of food.—BLR.

Fluorine Corrosion. W. R. Myers and W. B. DeLong, *Chem. Eng. Prog. (Trans. Sect.)*, **44**, 359-362 (1948) May.

First section deals with corrosion of a number of metals and alloys by hydrogen fluoride and by hydrogen fluoride-steam mixtures at elevated temperatures; second section gives results of an investigation on behavior of steel parts anodically charged in an electrolyte of KHF_2; HF at 90° C. 11 ref.—BLR.

Contribution to the Question of Water-Vapour Corrosion of Zinc Alloys Containing Aluminum. IV.—On the Influence of Lead (and Magnesium). Karl Lohberg, *Metallforschung*, **2**, Nos. 7/8, 230-232 (1947).

The distribution of lead in a eutectic alloy containing zinc 95 and aluminum 5 percent was examined by additions of lead and its radio-active isotope, thorium B, and the effect of the lead and of addition of 0.2 percent magnesium on the corrosion-resistance was studied. After 18 hr. at 95° C. in a moist atmosphere, corrosion had commenced; the alloy containing 0.7 percent lead was completely disintegrated after two days,

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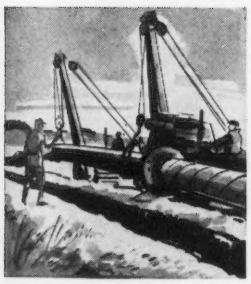

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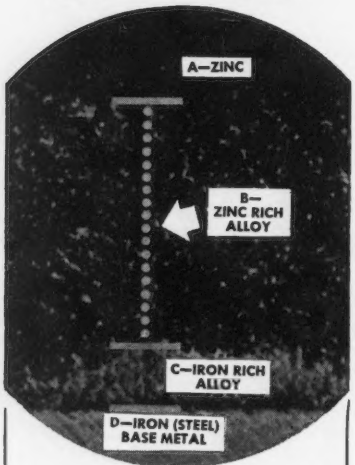

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while the alloy containing 0.4 percent lead took 3-4 days to reach a similar state. The lead is concentrated as large globules at the grain boundaries of the eutectic crystals, and it is in these places that corrosion begins. On addition of magnesium the lead probably is converted to Mg_3Pb and, although still inter-crystalline, is more finely dispersed and evenly distributed. The corrosion-resistance of the magnesium-containing alloys is greater than that of the magnesium-free alloys, but this is partly due to the reduction in crystal size brought about by magnesium.—MA.

Case Histories of Industrial Corrosion Point a Moral. F. L. LaQue, Inco, Paper before ASM, Chapter Mtg., New Haven, Conn., *Metals Review*, **21**, No. 1, 23 (1948) Jan.

Case histories were cited to demonstrate the futility of generalizations concerning the corrosion resistance of a particular metal to a particular chemical or substance. In studying the corrosion of a dairy regenerator, test pieces were placed in various parts of the equipment and it was found that nickel was resistant to corrosion by milk when the heat was flowing from the nickel to the milk, but when flowing in the reverse direction, the nickel corroded. The direction of heat flow governed protective film formation. A study of corrosion rate on nickel tubes in caustic soda evaporators showed that sulfur compounds in lower states of oxidation caused rapid corrosion, but when these were oxidized to sulphate, the corrosion rate was reduced. Certain machines containing Monel parts used for dyeing silk stockings gave trouble; those machines were equipped with tight-fitting doors. The dye in these machines tended to change color. Loose-fitting doors permitted influx of air to keep the dye oxidized to true color.—INCO.

A Note on the Reactions Between Water Vapour and Hydrogen Peroxide and Light Metals at Elevated Temperatures. Oswald Kubaschewski and Hans Ebert, *Metallforschung*, **2**, Nos. 7/8, 232-235 (1947).

The differing rates of reaction of magnesium and aluminum with water vapor and hydrogen peroxide at 400°-700° C. are due to the differing vol. quotients, $^{v}oxide/^{v}metal$. For magnesium the ratio is 0.81 and for aluminum 1.50, so that whereas for magnesium the deciding factor in the reaction velocity is the amount of water vapor present, in the case of aluminum it is the rate of diffusion of aluminum through the aluminum oxide film. Magnesium-aluminum alloys behave as if both metals are present in the unalloyed condition.—MA.

Investigation on Corrosive Matter in Meters. Stanley Jones and J. A. Speers, *Gas J.*, **254**, 40 (1948) Apr. 7.

Presents results of a study of the effects of ammonia in the gas on corrosion of tinplate.—BLR.

COATINGS

Effects of Red Lead (and Zinc Chrome) Paints on the Quality of Metal Arc Welds in Structural Steel. R. W. Bennett, R. D. Williams & C. B. Voldrich, *Welding J.*, **26**, (1947), *Welding Res. Council Suppl.*, 653-s; *J. Brit. Ship-building Res. Assoc.*, **3**, No. 2, 55 (1948).

While red lead and zinc chrome paints in thicknesses of about 1 mil may be used to protect steel prior to welding, there is some doubt as to advisability of this if welds of best notch characteristics are desired.—RPF.

Standard Salt Bath for Aluminum Coating of Steel. *Light Metal Age*, **5**, No. 11, 16 (1947).

The Upton method of coating steel with aluminum is described. The steel, after cleaning, is immersed first in a fluxing salt bath at 700°-1000° F. (371°-538° C.) and second in a bath containing salt at 1600°-2000° F. (871°-1093° C.) on which the aluminum floats. Both baths are electrically heated. The coating has all the corrosion-resistant properties of aluminum, and underneath it is a layer of very hard aluminum-iron alloy. It is claimed that better adhesion is obtained than by other methods, and that photomicrographs show a remarkable continuity of bond.—MA.

Temporary Rust Prevention Treatments. *Agric. Eng. Rec.*, 180-184 (1946-7) Winter.

Various treatments were evaluated by applying a series of commercial products to parallel sections of a steel plow moldboard and exposing it to the weather for several months. Results are described, illustrated, and tabulated.—BLR.

Chemical Treatments for Zinc Surfaces. H. A. Holden, *Sheet Metal Ind.*, **24**, No. 246, 1975-83 (1947); *Z.D.A. Abs.*, **5**, No. 11, 735 (1947).

A discussion of the adhesion of paint on zinc surfaces, and of chemical treatments for such surfaces. 67 refs.—RPI.

Bibliography of Reports on Protective Coatings for Metals. Office of Technical Services (Oct. 1947) 49 pp. (TA-468, T-25).

This bibliography lists in order of PB number, number of pages, date, cost, and a brief abstract for each article. The highest PB number is 79507.

Anti-Fouling Compositions for Aluminum Alloys. Admiralty Corrosion Committee, Final Report ACC/H120, 1/46; *J. Brit. Shipbuilding Res. Assoc.*, **2**, No. 7, 246 (1947).

Exposure tests were carried out on panels painted with protective and anti-fouling systems submitted by various proprietary manufacturers as suitable for application to aluminum alloy under-

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water plating. The alloy used for the panels was one with inherently high resistance to corrosion in sea water. Further work will be necessary before a satisfactory solution to the problem of the effective protection of aluminum alloys against fouling is found.—RPI.

Tin Undercoating Improves Rust Resistance of Steel. Tin Research Institute of America, *Iron Age*, **160**, No. 17, 45 (1947) Oct. 23; *Austin Tech. News*, No. 215, 5, (1947).

The use of an extremely thin coating of tin (0.00005" thick) on mild steel, before painting, provides an exceptionally good rust-resisting combination. The cost involved in applying the tin to both surfaces of a sheet is estimated at less than a quarter that involved in painting one side of the sheet.—RPI.

American Anti-Corrosive and Anti-Fouling Paints. U. S. Navy Department, *Engineer*, **184**, 474-6 (1947); *Bull. Brit. Non-Ferrous*, **27**, No. 222, 364 (1947).

An account of work on treatment of ships' bottoms for protection against corrosion and fouling, giving details of technique of application of paints, but not of composition.—RPI.

Painting Aluminum Structures. Robert I. Wray and Junius D. Edwards, *Paint, Oil and Chem. Rev.*, **111**, 16, 46, 48+ (1948) Apr. 15.

Describes recommended procedures for surface preparation and for paint selection and application. Performances of different paints on different aluminum alloys, and under different service conditions are described and illustrated by test-panel photographs.—BLR.

Corronizing Processes. *Wire and Wire Prod.* **23**, 311, 343-348 (1948) Apr.

Describes and illustrates use of nickel-zinc and nickel-tin in the protection of steel articles against corrosion.—BLR.

Some Recent Developments in Synthetic Resins for Protective Coatings. L. R. Whiting, *American Paint*, **32**, 72, 74+ (1948) Apr. 19.

Discusses studies and results obtained in an attempt to produce a coating that would serve both as an inhibitive wash coat and a temporary anti-corrosive primer. Also briefly describes an instrument, the "Protectometer," for evaluating protective films on metal in various environments.—BLR.

Painting Aluminum. A. J. Ward, *Electroplating*, **1**, 309-314 (1948) May.

Deals with solvent, chemical, and electrolytic methods of cleaning and degreasing and with mechanical and chemical methods of etching or slightly roughening the surface prior to painting or enameling.—BLR.

The Metallizing of Glass and Plastics by the Reduction of Aqueous Solutions. Patrick B. Upton, *J. Electrodepositors' Tech. Soc.*, **22**, 45-72 (1947).

Reviews the older processes and their newer modifications and collates the new techniques now being employed and de-developed under the following heads: 1) preparation of surface, 2) general consideration of silvering processes and their applications, 3) particular silvering processes, 4) metals other than silver, and 5) metal films as a basis for electrodeposition. Data for some of the processes are summarized in tabular form, and a bibliography of 126 references, including earlier surveys of the subject, is included.—MA.

Hot-Dip Tinning on Coiled Strip (Sherman Process). *Tin Printer*, **23**, No. 266, 12-13 (1947).

A brief description of the Sherman process for the continuous hot-dip coating of tin on coiled steel strip. The strip is uncoiled from a drum, passed successively through pickling baths and water baths, and then is passed through a heating chamber prior to entering a bath of molten tin. After leaving the tin-bath, the strip passes through two spraying devices designed to remove excess plating material from the strip, and finally is coiled on a motor-driven drum. Details of the operation of the plant are given, and it is claimed that a greater rate of output is obtained at a lower production cost than when using older processes. Accurate control of the thickness and uniformity of the coating is possible and the "dripedge" effect is eliminated. —MA.

Uniform Tank Coatings. R. W. Thrasher, *Steel*, **122**, 76-80+ (1948) Apr. 19.

Describes and illustrates use of a completely conveyorized setup for hot-dip galvanizing, assembly, and resistance welding of tank shell and head units and separate dome-shaped bottoms. Relative concentration of zinc in and around weld area and other problems affecting effi-

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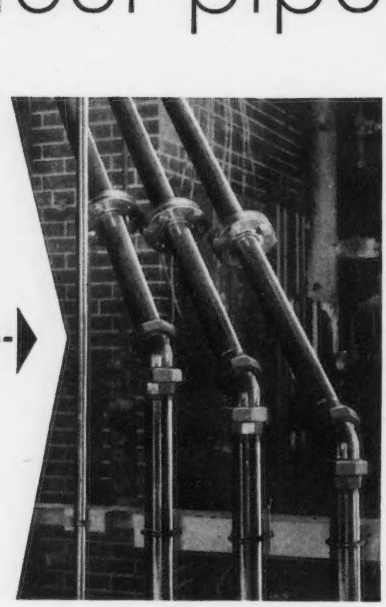

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ciency of finished tanks were studied carefully to develop the fabricating methods followed.—BLR.

Application of Zinc Coatings by Hot Dipping. Robert Steele, *Metal Finishing*, **45,** No. 12, 71-76 (1947).

A review of the whole field of galvanizing. Equipment for pickling and galvanizing is described, and the character of the coating and the influence of the base metal briefly examined. Reference is made to the spelter bath containing small amounts of lead, tin, iron, cadmium, copper, or aluminum.—MA.

Recent Developments in the Use of Conversion Coatings on Zinc. J. E. Stareck and W. S. Cibulskis, *Proc. of the American Electroplaters' Society*, 171-178; Discussion, 178-179 (1948).

A brief review of the various electrolytic and dip-type conversion coatings on zinc is given. Tables for outdoor corrosion resistance correlated with standard salt-spray results are included covering both white corrosion products and rusting. Resistance is correlated with thickness of plate, effect of impurities, and type of coating applied. Successful commercial uses of clear and colored coatings are described.—BLR.

Zinc as an Anti-Corrosive. A. H. Smart, *Paint Manuf.*, **17,** No. 11, 383-385 (1947).

A short discussion on the electrochemical behavior of zinc in preventing the corrosion of iron when in contact with it in an aqueous solution. Some simple experiments also are described which indicate that zinc exerts a certain protective effect even if there is no actual contact, possibly by raising the pH of the electrolyte. The use of zinc dust as a paint pigment is briefly mentioned.—MA.

The Protective Treatment of Metals. H. Silman, *Metallurgia* (England) **37,** No. 222, 322-323 (1948) Apr.

In this book, the author set out to present a broad survey of finishes that are commercially applied to metals from aqueous solutions with or without the use of electric current. The corrosion of the common metals of engineering is covered briefly. Descaling and pickling processes are comprehensively treated, attention being given to hydrogen embrittlement, the use of inhibitors and wetting agents, and the role of chromic acid in nitric/sulphuric acid dips. The section on polishing includes various methods, manual, automatic and barrel, the wheels and the compounds, and electro-polishing; in that on degreasing and cleaning, is included plant, process and materials for solvent, aqueous alkali and electrolytic methods (the value of wetting agents in the aqueous solutions is demonstrated). A section is devoted to metal coloring for decorative and light duty finishes; and a summary of processes for giving various colors on all metals, steels, coppers, brasses, cadmium, zinc and aluminum is given. With reference to electroplating, plant and equipment are discussed in general terms. In respect to the finishing of aluminum and magnesium light alloys, the principal anodizing processes are considered, including dyeing and sealing, and special processes for reflectors. Chemical immersion processes for aluminum are described briefly, i.e., M.B.V. and Pylumin, also electroplating processes. Magnesium alloys are treated very tersely on the basis of chromate immersion and anodic treatments.—ALL.

CONDENSATE WELL

Testing and Selection of Inhibitors for Corrosive High Pressure Condensate Wells. D. A. Shock, *Corrosion*, **4**, 179-185 (1948) Apr.

Reviews methods thus far devised for testing inhibitors and requirements of a satisfactory inhibitor. 23 ref.—BLR.

Corrosion and Preventive Methods in Katy Field. R. C. Buchan, *Petrol. Eng.*, **18**, No. 10, 159-172 (1947).

Corrosion problems in the producing and cycling equipment at this gas-condensate field are surveyed. B. deals mainly with ferrous metal corrosion, but mentions Stellite and hard chromium coatings for resisting erosion.—MA.

Alloying Steels for Corrosion Resistance to Gas-Condensate Fluids. Part 2. C. K. Eilerts, F. Greene, F. G. Archer, B. Hanna and L. M. Burman, Bureau of Mines, *Corrosion* **4**, 321-357 (1948) July.

Investigation was made of a large number of metals and alloys when in contact with corrosive media that may be encountered in gas-condensate wells. The procedure comprised a series of 7-day tests in which specimens were immersed in propionic acid and carbonic acid, and some also were corrosion-tested in phenol. Results were examined according to the type of material, percentage of alloying elements, corrosion susceptibility, etc. In investigating platings as a means of protecting steel against corrosion, steels plated with copper and nickel or coated with zinc were subjected to the 7-day test in the three corrosive mediums. In general, the corrosion resistance of the plated and coated steels was closely related to the rates of corsion of the covering materials. Tests were made to determine the rates of corrosion of chromium and nickel steels in corrosive mediums containing different concentrations of sodium chloride, and to determine if sodium chloride brines, produced with corrosive gas-condensate fluids, increase or otherwise modify rates of corrosion of alloy steels. The liquid-water phase of flowing gas-condensate fluid is the corrosive phase, and if a film of hydrocarbon condensate covers a metal surface so that water does not come in contact with it, the metal will not corrode. To determine whether certain alloys were more susceptible than others to preferential wetting by condensate, wetting tests were made on 11 metals. A factor that should be considered in selecting alloy tubing for service in gas-condensate wells is the resistance of the alloy to the corrosive action of hydrochloric acid. The rates of weight loss of 19 representative steels, alloys, and alloy steels were determined in 15 percent acid with four different commercial inhibitors at 130° and 300° F. A discussion is presented which examines the test methods in comparison with field exposure.—TDD.

OIL WELL

Corrosion Fatigue of Oil Well Equipment. B. B. Morton, International Nickel Co., *World Oil*, **127**, No. 13, 156, 158+ (1948) Apr.

The article covers phases of an investigation of corrosion-fatigue phenomena which must be considered in any program looking toward the reduction or elimination of equipment failures due to stress corrosion. Fatigue failure, the corrosion of steel and the corrosion fatigue of drill pipe and sucker rods are examined, and suggestions are made for overcoming these types of corrosion. The effects of oxygen, water, notches, scratches, and sharp changes in the dimensions of steel are discussed. The use of coatings or nickel with the steel for the prevention of corrosion is described.

Progress in Metals—Reda Pump Employs Corrosion-Resistant Alloys. W. L. Nelson, *Oil and Gas J.*, **46**, No. 7, 95 (1947) June.

In the development of the Reda centrifugal oil-well and brine-well pump, difficulty with corrosion was met. When handling brines of certain formations in Michigan, the alloy-steel shaft and gray-iron diffusers failed rapidly by corrosion. Since replacing the shaft with K-Monel and the diffusers with Ni-Resist iron, the difficulty has been completely eliminated.—INCO.

Prevention of Drill String Failures in the Permian Basin. Part I. Robert C. McMaster, *World Oil*, **127**, 75-80, 82 (1948) Apr.

Summarizes methods followed in research on the above problem at Battelle Memorial Institute and offers conclusions based on observed results.—BLR.

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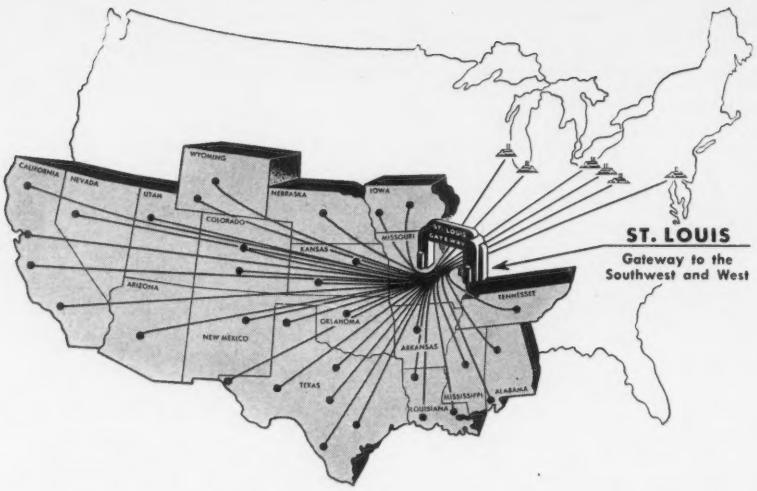

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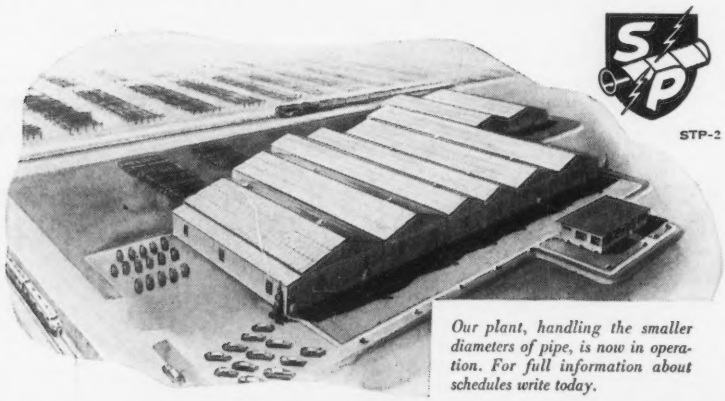

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CONSTRUCTION MATERIAL

B-W Digesters to be Chrome-Alloy Lined. *Paper Trade J.*, **124,** No. 14, 26 (1947) Apr. 3.

The first alloy-clad digesters to be furnished the industry by Babcock and Wilcox are lined over the entire inner surface with B & W Croloy 13 bond, using AISC alloy 410 or 410, which contains 13 percent chromium. Between steel and alloy is a thin layer of nickel which prevents carbon migration from steel to chromium at fusion temperatures of resistance welding. By use of nickel, grain growth and embrittlement are eliminated at junction zone of the bond. Nickel also serves to act as a soft ductile layer between steel and chromium. Liner is integrally bonded over entire area with small resistance welds which overlap. The bonded plate then is heat treated at approx. 1600° F. which replaces the chromium alloy in its original corrosion-resistant state and checks the integrity of the bond. Vessels are designed to work at 150 lbs. pressure up to 650° F., although usual working temperature will be around 340° F.—INCO.

18-8 Steel in Exhaust Systems. W. G. Hubbell, *Aero Digest*, **55,** 92, 95+ (1947) May.

Report of work at metallurgical laboratory of Ryan Aeronautical Co. on question whether the stainless steel used in aircraft exhaust manifolds picks up carbon from the exhaust gases which might affect the corrosion resistance of the metal. Pick-up was found to vary from 0.023-0.06 percent. Types of corrosion observed are described. Work on the formability and weldability of 18-8 sheets is reported.—INCO.

The Problem of the Perforating Corrosion of Centrifugal Grey Cast Iron Tuveres. A. Collaud. Paper before Journess Metallurgiquas d'Automne (Fall Metallurg. Conf.) sponsored by Soc. Francaise de Metallurgie and Comm. Tech. des Etats de Surface, Paris, Oct. 6-10, 1947, (Abst. in French).

Control of the furnace atmosphere is the only preventive measure discussed.—INCO.

The Attack in Controlled Atmospheres of Nickel-Chromium Alloy Electrical Resistance. E. H. Buckwall and L. E. Price, Paper before Journees Metallurgique d'Automne (Fall Metallurg. Conf.) sponsored by Soc. Francaise Metallurgie and Comm. Tech. des Etats de Surface, Paris, Oct. 6-10, 1947. (Abst. in French.)

Description is given of experimental work carried out on a type of attack affecting nickel-chromium alloys heating in controlled atmospheres at temperatures of about 950°. Typical examples of deterioration in service are described as well as laboratory studies. Chromium carbide is formed followed by oxidation of the carbide. In laboratory the attack can be reduced by adding sulfur to the controlled atmosphere. Iron and silicon additions to the nickel-chromium alloys considerably diminish their deterioration. —INCO.

Erosive Effects of Gun Blasts on Materials—Development of a Strong Brittle Alloy. J. A. Broadston, North Am. Aviation, Inc. Paper before A.S.T.M., 50th Ann. Mtg., Atlantic City (1947), June

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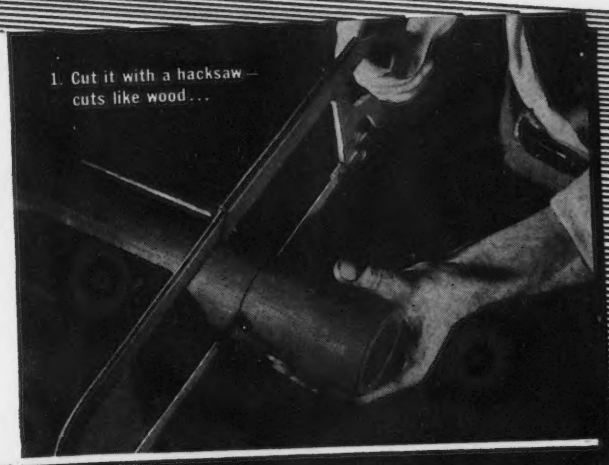

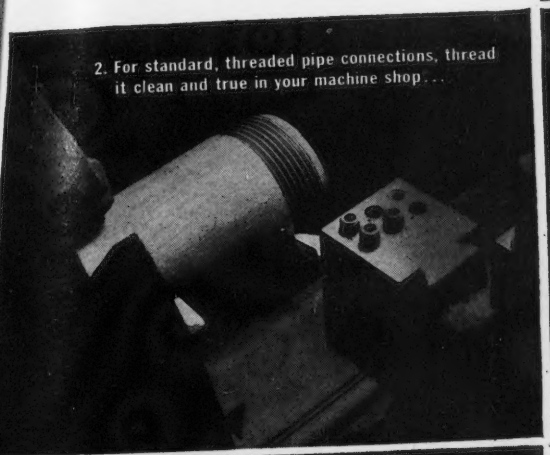

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16-20. *A.S.T.M. Bulletin,* No. 148, 39-43, (1948) Oct.

Description of development tests of a material suitable for gun-port doors of high-speed combat aircraft. Requirements where strength and ductility adequate to withstand the repetitive impact, heat and erosion of explosive gases at gun muzzle and frangibility so that in event of inadvertent firing, doors would be shot off without damage to aircraft. Tests of muzzle-blast effect were conducted by North American Aviation on various metals, ceramics and plastics to determine erosion and temperature resistance required. A high copper-magnesium-aluminum frangible cast alloy (NAA Spec. NA-2-9906) was selected. Further tests were conducted to develop a corrosion-resistance treatment for withstanding action of muzzle-blast deposit. Corrosion was due to chemical action between aluminum alloy crystals and alkaline gun-blast deposit. High copper eutectic and constituents at the grain boundaries were untouched due to fact that both deposit and matrix are high in copper and cathodic with respect to aluminum alloy crystals. This limits corrosion to first exposed layer of crystals. Aluminiting (An-QQ-A-696) and use of alkaline dichromate treatment (Alroking) per Army Spec. 98-20007 seem satisfactory, although corrosion tests on treated specimens have not yet been completed. Photomicrographs show fractured sections and corrosion product.

TESTING

Polarographic Study of Corrosion Phenomena. P. Van Rysselberghe, J. M. McGee, A. H. Gropp, R. D. Williams and P. Delahay, *Cor. and Mat. Prot.* **5,** No. 2, 11-16 (1948) March-April. *Ind. and Eng. Chem.* **40,** 16 A, 22 A (1948) Apr.

A group at the University of Oregon has advanced the idea of using the polarograph as a tool in the study of corrosion phenomena. According to their search of the literature this idea was new. The types of corrosion which come within the scope of a polarographic approach are as follows: the corroding materials include, in principle, all metals and alloys; the corrosive media are aqueous solutions, salts, acids or bases containing in addition oxygen (pure or dissolved as air), carbon dioxide (pure or again dissolved as a component of air), any arbitrary mixtures of oxygen and carbon dioxide, various substances which, either from the theoretical or the practical point of view, may be expected to play a part in corrosion, such as small amounts of hydrogen peroxide (a possible intermediate in the reduction of oxygen), protective substances such as chromates, etc. The polarograph is an instrument which records reduction currents resulting from the application of gradually increasing cathodic potentials to a dropping mercury electrode. The application of the method to corrosion is based upon the fundamental idea that consumption of such compounds as oxygen, carbon dioxide, hydrogen peroxide, hydrogen ion, etc., by metallic surfaces dipping in electrolytic solutions containing these compounds can be followed through the variation with time of their polarographic reduction currents. In this manner very sensitive and very rapid corrosion tests can be carried out, because of the remarkable sensitivity of the polarograph to minute changes of concentrations of reducible substances. In some cases the corrosion process includes the dissolution of some of the metal as aqueous ions and these ions will themselves undergo polarographic reduction. The most important substance in corrosion by aqueous media is oxygen, whose role as a "cathodic depolarizer" in the local galvanic couples formed on metallic surfaces is discussed at length in the literature of corrosion. It also can play a protective role through formation of oxide films. Consumption of oxygen is therefore one of the main processes one should follow in quantitative corrosion studies. The polarograph furnishes an ideal method of following oxygen concentration changes, according to the well-established two-step reduction: O_2 to H_2O_2, H_2O_2 to H_2O. The corrosion studies have included thus far determinations of consumption of: Oxygen by pure metals and alloys; of carbon dioxide by metals and alloys; of hydrogen peroxide by metals and alloys; determination of simultaneous consumption of oxygen and carbon dioxide and of hydrogen peroxide and carbon dioxide by metals and alloys; investigations on a possible role of hydrogen peroxide in corrosion; and investigations on a possible role of percarbonic acid in corrosion. Consumption of hydrogen ion by metals, i.e., corrosion by acids is also being studied. Corrosion by electrolyte solutions entirely deprived of oxygen and carbon dioxide has been studied to a certain extent through the appearance of metallic ions of the corroded metal. The interests of the group at the University of Oregon is primarily towards the fundamental physical chemistry of corrosion rather than towards technical and practical studies of the many-sided aspects of corrosion. This paper includes the introduction, experimental technique, analysis and interpretation of polarograms. In a subsequent communication the authors will present the essential observations made in their application of the polarographic method to the corrosion of several metals and alloys. The work reported is part of a research program supported by the Office of Naval Research under contract with the University of Oregon.—ALL.

Drop Test for Determining Thickness of Zinc Coatings. Richard Springer, *Monthly Rev. Amer. Electroplaters' Soc.,* **34,** No. 10, 1147 (1947).

An account of a method which has been used widely in Germany for many years. One drop of a solution containing 120 g./l. chromium trioxide and 35 g.l. sulphuric acid is placed on the degreased surface at 20° C. After 15 sec. it is removed rapidly with an absorbent cloth and replaced by another drop. The procedure is repeated at the same point until the base metal appears. Each drop applied for 15 sec. is equivalent to 0.000039 in. zinc. This figure applies to deposits from alkaline plating solutions containing sulphides. For deposits from other solutions a different factor has to be used.—MA.

Testing Acid-Resisting Steels for Their Resistance to Intercrystalline Corrosion. S. Plankensteiner, *Metallurgia,* 36, No. 213, 145-148 (1947) July.

A report is given, based on experiments and tests, on the best method of determining resistance to intercrystalline corrosion of austenitic chromium-nickel

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and chromium-nickel-molybdenum steels. Various testing liquids investigated included Hatfield's $H_2SO_4 + CuSO_4$ solution, 10% $HNO_3 + 1\%$ H_2SO_4, 10% $HNO_3 + 10\%$ H_2SO_4, 1% H_2SO_4, and 0.5% H_2SO_4. Resistance to the Hatfield solution does not prove the resistance to intercrystalline corrosion. Resistance to pure H_2SO_4 is more reliable. By use of a 0.5% solution testing time can be reduced to one-third the time required with $CuSO_4 + H_2SO_4$ solution. Specimens are shown and results given of tests on a melt of 17.81 chromium 9.80 nickel-2.02 molybdenum steel in both 0.5% H_2SO_4 and the $CuSO_4 + H_2SO_4$ solution. The former test, carried out for 24 hours gave similar results to the latter, which required 72 hours. Full details are given of testing equipment and method. A graph shows influence of drawing temperature and its duration on susceptibility to intercrystalline corrosion of an 15.2% chromium-10.9% nickel steel. Specimens for welding and for sound and bend tests are shown.—INCO.

First Report of the Methods of Testing (Corrosion) Sub-Committee. *J. of the Iron and Steel Inst.*, **158**, 463-493 (1948) Apr.

Describes work of the above sub-committee on the basis of which Provisional British Standard No. 1391:1947, "Performance Test for Protective Schemes Embracing Stoving Paints Used in the Protection of Light-Gauge Steel and Wrought Iron Against Corrosion," was compiled. After investigations of a number of different methods of testing, a sea-water spray test devised at the Armament Research Department was selected as the most suitable for this purpose and was standardized to ensure reproducibility of the results. Reasonable standards of performance in this test for protective schemes embracing single coats of stoving paints applied over phosphated or non-phosphated steel were determined by means of tests on typical industrial finishes of these types, the results of which are recorded. Concludes with a statistical analysis of the test results.—BLR.

"Protalization"; a Simple Chemical Treatment of Light-Alloy Surfaces. E. Jaudon. *Rev. Aluminum*, No. 134, 199 (1947).

A brief account of corrosion-test results on aluminum and Duralumin specimens submitted to saline mist.—NA.

Measuring Rate of Metal Corrosion. *Chem. & Eng. News*, **26**, No. 13, 950 (1948) Mar. 29.

A pulse polarizer designed to measure rate of corrosion or dissolution of metal in corroding medium essentially consists of a high voltage pulse circuit, electronic polarization detector and high-speed recorder. Metal to be studied is polarized over a brief time interval either cathodically or anodically, and the polarization and depolarization processes continuously recorded. Data are easily reproducible and for many systems lead to an immediate evaluation of the corrosion rate. Instrument may be used to determine proper inhibitor concentration and as an important tool in research to evaluate inhibitors. Unlike data from weight-loss experiments, the data are permanent and reproducible and may be obtained in a few minutes. Unit designed and manufactured by Glenn A. Marsh, Chicago.—INCO.

Quantitative Evaluation of Corrosive Conditions. W. F. Bonwitt and I. Eisen, *ASTM Bull.*, No. 151, 84-88 (1948) Mar.

The purpose of the work described in this article was to investigate a sensitive means for making quantitative comparisons between artificial procedures and natural corrosive processes. It was found possible to calibrate the effect of natural corrosion and of several artificial accelerated corrosion procedures on a metal by observation of the electrical resistance of a thin foil ribbon of the metal. With copper as the experimental sample, a linear relation was found between the duration of exposure to the corrosive procedure and the increase of resistance of the sample. This linear relation, which held true for natural corrosion and for all of the artificial procedures investigated, made it possible to develop a constant expressed as percentage in resistance per unit time for the effect of each corrosive procedure. From the data collected this corrosive effect constant was computed for each of the corrosive procedures investigated. The constant obtained for each process is significant, of course, only for the particular metal used for the foil. Further experiments will show whether this method can be applied to other metals and more complex conditions and to the quantitative evaluation of corrosive atmospheres present in various locations.—ALL.

ASTM Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. *ASTM Bull.* No. 151, 11-12 (1948) Mar.

The Sub-Committee on Total Immersion Corrosion Tests has formulated its plan to make some co-operative tests. The Sub-Committee on Spray Test discussed some refinements in the Method of Salt Spray (Fog) Testing (B117) and recommended the sponsoring of a paper on apparatus and factors in such testing. The Sub-Committee on Humidity Tests will enlarge its membership to include representatives of other ASTM main technical committees interested in humidity tests and will write up a method of humidity testing applicable to all types of materials. The Sub-Committee on Atmospheric Tests reported that the joint B-3-B-7 Committee on Atmospheric Tests on Magnesium Alloys had outlined a test plan which was now being considered by the members of the Committee B-7. The Sub-Committee on Galvanic and Electrolytic Corrosion will

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submit data on a five-year test of stainless steel coupled with other metals exposed to outdoor weather. Its program for exposing magnesium alloys coupled to other metals in outdoor atmosphere is progressing, and a large number of assemblies will be exposed this summer.—ALL.

Engineering the Tin Can. H. S. Van Vleet. *Mechanical Eng.*, **70**, 315-320 (1948) Apr.

Describes, briefly, engineering phases of can-making, corrosion resistance, and discusses steps taken toward conservation of tin. 14 ref.—BLR.

Corrosion Research in Canada. *Nature* (England) **161**, No. 4093, 553-554 (1948) Apr. 10.

The National Research Council, Canada, has established a committee to assemble information on all aspects of corrosion and promote its dissemination, and in this respect a survey is being made of existing Canadian facilities for the study of corrosion and means of combating its effects. It has been proposed to assist Canadian universities in making studies of the fundamental chemical and electrochemical reactions that cause deterioration of metals in service, and in the training of students in the techniques of corrosion research and prevention. The committee is seeking the co-operation of all organizations and industries concerned in dealing with corrosion problems. The chairman of the new committee is Dr. R. R. Rogers, Department of Mines and Resources, and the secretary, D. Wolochow, Division of Building Research, National Research Council.—ALL.

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INHIBITORS

Mechanism of Action of Corrosion Inhibitors. (In French.) Herbert H. Uhlig. *Metaux & Corrosion*, **22**, 204-210 (1947) Nov.-Dec.

Gives fundamental principles of the above. 33 ref.—BLR.

Inhibition of Steel Corrosion by Sodium Nitrite in Water. M. Cohen, Nat. Res. Council, Ottawa. Paper before Electrochem. Soc., Columbus, Ohio, Mtg. April 14-17, 1947. *J. Electrochem. Soc.* **93**, No. 1, 26-39 (1948) Jan.

A study is reported of the effect of sodium nitrite on corrosion of steel in water. Test methods included total and alternate immersion, a recirculation apparatus, and potential measurements. The concentration of sodium nitrite required to inhibit steel corrosion depends on conditions of motion and temperature. The mechanism of inhibition is probably the formation of a protective oxide coating. Graphs and tables present corrosion data and apparatus is fully described and shown.—INCO.

Sodium Nitrite as Corrosion Inhibitor for Water. A. Wachter, Shell Dev. Co. *Ind. Eng. Chem.* **37**, No. 8, 749-51 (1945) Aug.

Sodium nitrite is a good corrosion inhibitor for water and under many conditions can suppress completely the corrosion of steel. The concentrations of nitrite needed for pronounced inhibition vary with the severity of conditions and the pH and composition of the water. Sodium nitrite can completely prevent corrosive attack on steel in sodium chloride solutions and in aqueous alcohol solutions. It is also effective on steel which is covered with rust scale. Corrosion of many of the common ferrous and non-ferrous metals is either inhibited or not adversely affected by the presence of nitrite.—CEC.

Use of Soluble Inhibitors. U. R. Evans, Cambridge Univ., *Ind. Eng. Chem.* **37**, 703-05 (1945) Aug.

Factors deciding between corrosion and inhibition are discussed. When the immediate corrosion product is sparely soluble, attack is likely to be stifled. However, when the immediate product is soluble but a secondary product is only sparingly soluble, attack will usually continue. Anodic inhibitors function by forming a sparingly soluble anodic product. When the corrosion reaction is under cathodic control, anodic inhibitors are likely to be "dangerous" since, when added in insufficient concentrations, they tend to localize attack but may result in intensified attack at those areas which continue to corrode. Cathodic inhibitors form sparingly soluble products on the cathode areas. This type of inhibitor is likely to be "safe" since it does not cause intensification of attack. However, it is generally less effective in reducing total corrosion reaction than are anodic inhibitors. Several examples of both types of inhibitors are given in this paper.

Discussion of paper. D. S. McKinney and J. C. Warner, Carnegie Inst. Tech. pp. 705-06. Reply to discussion, 706. Evans—CEC.

Recent Developments on the Use of Corrosion Inhibitors. Jay T. Nicholson, *Corrosion*, **4**, No. 1, 32-36 (1948).

A simple laboratory test apparatus, simulating pipe-line conditions for determining the efficacy of inhibitors, is described. The factors influencing the choice of inhibitor (polyphosphate, chromate, silicate, chromate-phenol, amine, sulphite, or organic) are discussed.—MA.

INSPECTION

Symposium on Non-Destructive Testing. American Society for Metals. *Modern Machine Shop*, **20**, No. 11, 184-192 (even pages), (1948) Apr.

Brief notes of papers presented at a meeting on April 8, 1948, including papers dealing with two American G. E. instruments (for ultrasonic testing, and for comparing metal parts by their effect on impedance of a circuit); and with applications of the betatron to radiography.—BNF.

Sigma Electro-Pneumatic Gauge. *Machinery* (London), **72**, 236 (1948) Feb. 19.

Describes and diagrams system for measurement of holes which are inaccessible or too small to permit other mechanical or electrical method of gaging.—BLR.

X-Ray Thickness Gauge for Cold Rolled Strip Steel. W. N. Lundahl, *Elec. Eng.* **67**, 349-353 (1948) Apr. A condensation.

Gives details of construction and circuits of an X-ray thickness gauge for cold mill and other applications utilizing one photoelectric multiplier pickup and two X-ray sources. Range is 0.005-0.050 in. with accuracies up to 1%.—BLR.

A Survey of Patents, Publications on Non-Destructive Tests; Fourth Progress Report on Non-Destructive Testing of Drill Pipe. L. R. Jackson and others. *Drilling Contractor*, **4**, 64-75 (1948) Apr. 15.

Summarizes significant features of non-destructive test methods described in more than 200 patents and about 200 technical articles. The patented methods are classified by the nature of the energy field established in the test object, or by the method of measurement. The nature and critical features of non-destructive tests are discussed, and important drill-pipe properties are listed. The principle of operation of each method is briefly stated, followed by a discussion of the novel features and applications of the significant patents. Several hundred references.—BLR.

Non-Destructive Testing of Steel Castings; Report of the Steel Division Committee of A.F.A. *Trans. of the American Foundrymen's Assoc.*, **55**, 574 (1947).

Outlines new developments between Apr., 1946, and Apr., 1947. Includes annotated bibliography consisting of 12 items.—BLR.

FUNDAMENTALS

Seven Factors Determine Extent of Corrosion. H. O. Teeple, International Nickel Company. Paper before A.S.M. St. Louis, *Metals Rev.*, 21, No. 2, 27 (1948) Feb.

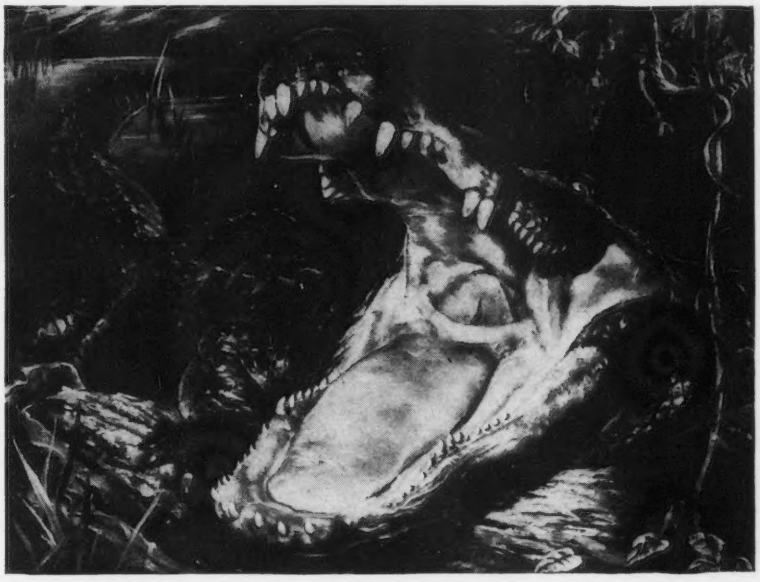
Fundamental reaction in corrosion of high-nickel alloys and stainless steels, involves a transfer of electrons in which + ions in corroding solution (usually hydrogen ions) lose electrical charges acquired by metal or alloy being corroded. Factors determining extent or progress of corrosion include acidity and oxidizing power of solutions, increase in temperature, velocity, effect of protective films, inhibitors, and effect of concentration cells. Others are surface conditions, effect of stress, heat treatment, welding and galvanic relationships.—INCO.

The Mechanism of the Corrosion of Aluminum. J. M. Bryan, *British Newspaper Chem. & Ind., No. 9*, 135-136 (1948) Feb. 28.

Properties of the oxide film are discussed in relation to the known facts concerning aluminum and the electrochemical theory of corrosion. A modification of the usual electrochemical explanation is suggested to account for the behavior of aluminum in alkaline solution. 13 ref.—BLR.

Grain Orientation in Aluminum Revealed by Anodic Film. A. Hone and E. C. Pearson, *Metal Prog.*, **53**, No. 3, 363 (1948) Mar.

When aluminum is anodized in certain electrolytes, the resulting film is optically active. The particular characteristics of this optical activity are essentially constant over any one grain but vary from one grain to the next. This variation is dependent on the orientation of the substrate crystal. Thus, a study of the orientation may be made by examining these films in polarized light. If plane polarized light is used as the



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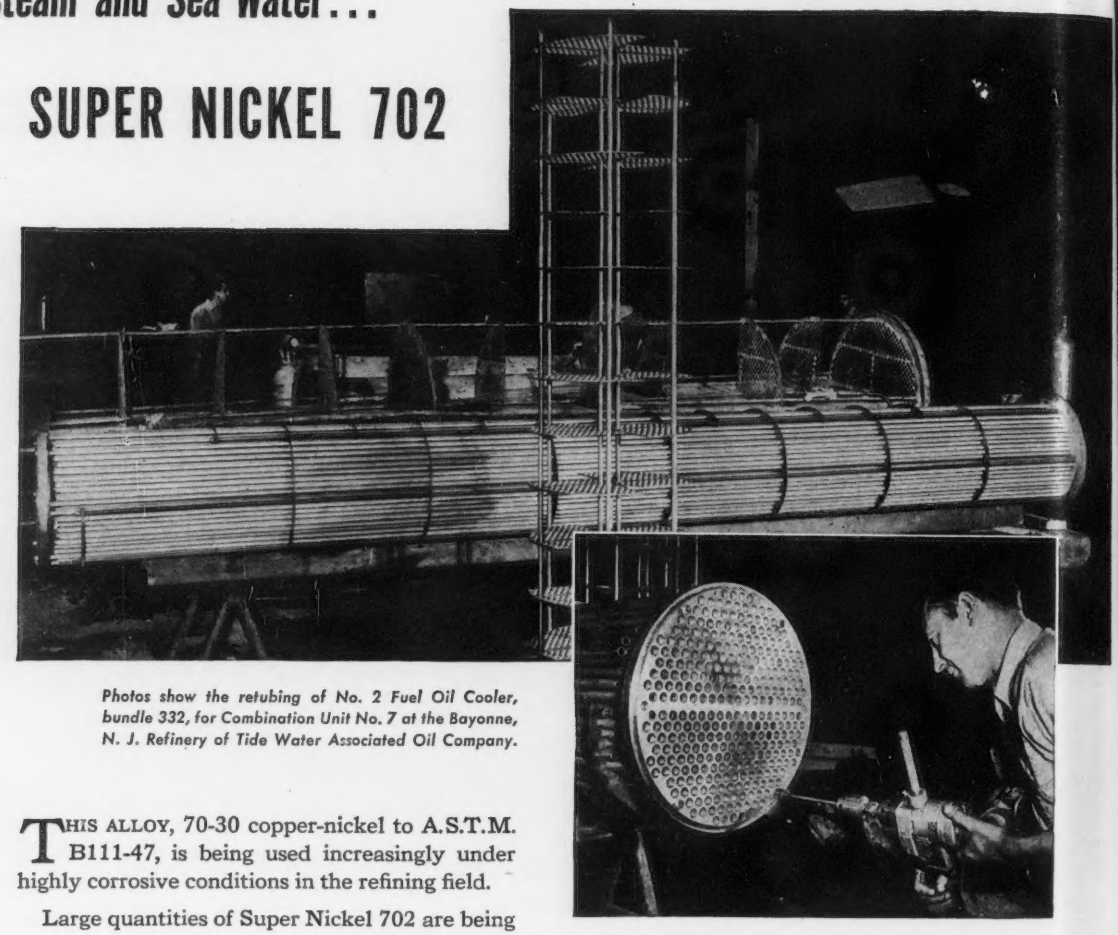

Photos show the retubing of No. 2 Fuel Oil Cooler, bundle 332, for Combination Unit No. 7 at the Bayonne, N. J. Refinery of Tide Water Associated Oil Company.

THIS ALLOY, 70-30 copper-nickel to A.S.T.M. B111-47, is being used increasingly under highly corrosive conditions in the refining field.

Large quantities of Super Nickel 702 are being used by the Tide Water Associated Oil Company in its Bayonne, N. J. Refinery. Considerable retubing of heat exchangers cooled by salt water was undertaken during 1947, and the work continues.

Here, it was necessary to find a tube material that would resist not only the destructive forces commonly encountered in petroleum cracking and refining but withstand as well the action of a corrosive coolant, salt water from Bayonne harbor.

In determining the most suitable metal to meet your own heat exchange problems, the broad experience and metallurgical knowledge of our Technical Department is at your service. Anaconda Condenser and Heat Exchanger Tubes are available in eleven standard and several special alloys, and are precisely controlled through every step of manufacture.

Anaconda Publication B-2, sent free on request, contains further information on tubes and plates for heat exchange applications. 48131

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ource of illumination and the magenta int retardation plate is inserted, each rain assumes a characteristic color. hese colors are complementary to the ave-lengths which have been extinuished by interference. The film, being nisotropic, introduces a phase shift, the mount of which determines the wavength which will be extinguished. Prerred orientation is manifested by the revalence of the magenta tint over a rge number of grains when the stage s rotated to the appropriate position. ertain quantitative information regardng the orientation may be gained by measurement of the extinction angles and the phase shift introduced by the film. The electrolyte used in this work was as follows:

Orthophosphoric acid (85%)	70.0%
Distilled water	2.5%
Diethylene glycol monoethyl ether	26.5%
Hydrofluoric acid (48%)	1.0%

A potential of 50 volts was applied while the current density was maintained at 20-50 milliamperes per square inch.—ALL.

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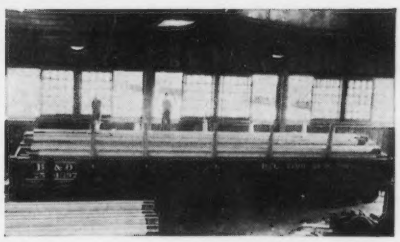

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REFINERY

Maintenance of Stainless Steel Equipment in Refineries. Part II. Stress and Local Corrosion, Wear and Abrasion, and Cleaning Methods. W. G. Renshaw, Allegheny Ludlum Steel Corp., *Petr. Proc.*, **3**, 155-6, 159-60 (1948) Feb.

Operating conditions in stainless steel equipment which contribute to stress-corrosion include pressure reversals, cyclic vibrations, nonuniform heating, brines, contact with other metals, coke and other surface contaminants, wear and abrasion, etc. Each is discussed briefly with remedial steps to be taken to overcome them.

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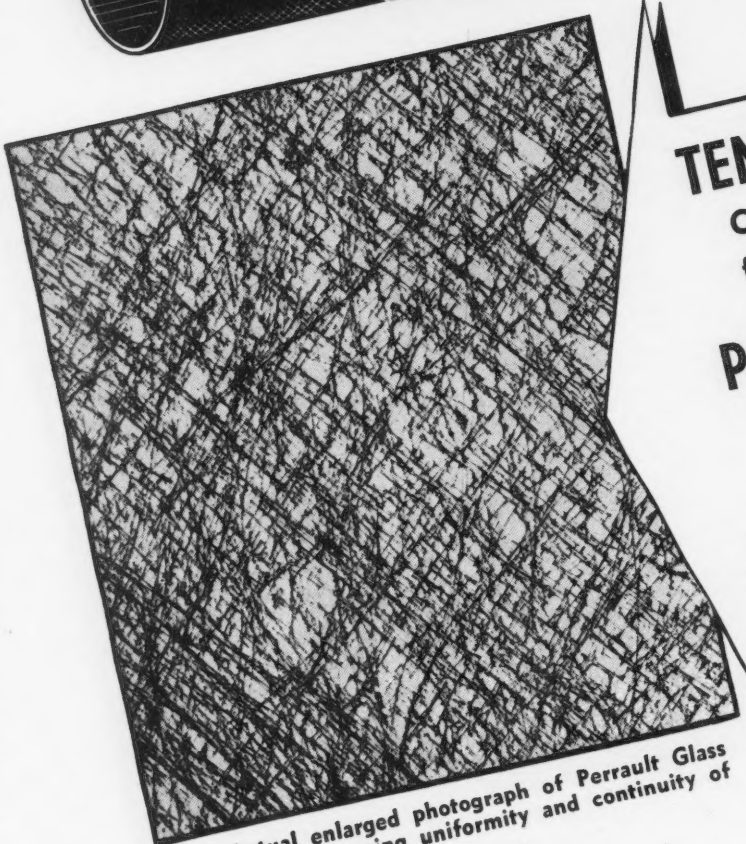

● Actual enlarged photograph of Perrault Glass Pipe Wrap, showing uniformity and continuity of glass fibers.

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DURIMET 20—a high Ni-Cr-Mo-Cu low carbon stainless steel. For sulfuric and sulfurous acids, oleum, caustic, and other solutions. Bulletin 112.

CHLORIMET NO. 2 — nickel-molybdenum alloy; **CHLORIMET NO. 3**—nickel-molybdenum-chromium alloy. Chlorimet No. 2 for HCl in all concentrations and temperatures. Excellent for hot H_2SO_4 under reducing conditions and wet hydrogen chloride gas. Chlorimet No. 3 for most acids under oxidizing conditions, various salt solutions, hot sulfuric in concentrations of less than 35%. Bulletin 114.

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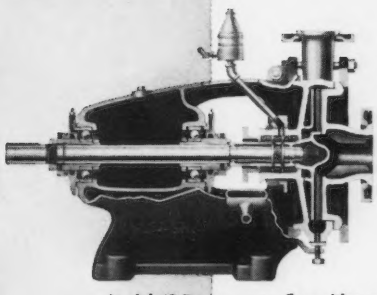
WHICH ALLOYS TO USE—*Write for Bulletin 100. It lists 155 corrosives and tells which Durco alloys handle each. For information on specific alloys and equipment, write for the bulletins mentioned above.*

Durco Adv. 69-GM



Model 40 Durcopumps. Capacities up to 2,000 GPM; heads as high as 230 feet. Bulletin 815.

Durco Valves are made in a variety of popular types including Y and Angle Valves, Bul. 615, Plug Valves (Lubricated and Non-Lubricated) Bul. 617, 618 and 635, Diaphragm Valves, Bul. 623A.

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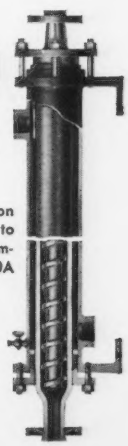

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